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Reinforced Concrete—Theoretical Principles of Design.

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INTRODUCTORY.

THE past decade has seen a tremendous development in the method of construction known as reinforced concrete. Concrete, which has been used for centuries as a material of construction, was found to possess very little tensile strength, and over fifty years ago suggestions were made to make up for this weakness by embedding iron rods or lathing in the portion of the structure in which tension would occur. This was applied chiefly to floors, and although there are early records of tests of concrete slabs thus "reinforced," it has been only recently that efforts have been made to apply theoretical knowledge to such structures and so to design them upon a scientific basis. With their natural objection to trying new methods which have not stood the test of time, English engineers have been slow to adopt the reinforced concrete construction, and so the greater part of the work has been executed on the Continent and in America.

Now, the full theory of reinforced concrete is not yet standardised, and so there is a very large amount of experimental data and theoretical investigations which require to be digested by those who wish to understand the principles of design. These data and investigations are very dangerous to the uninitiated, because they usually relate to definite qualities of materials and certain special conditions, and one can easily get into gross error in applying a formula when one does not know the meaning of each of the terms in it and cannot therefore judge whether the formula is applicable to the problem in hand. The aim of the present article is to set out the fundamental principles upon which the theoretical design of reinforced concrete is based, and thus to enable the reader to follow more easily the more complicated investigations

which are to be found in the standard text-books on the subject.

Now, the efficiency of any design depends on whether it is as cheap as possible for the given conditions, and therefore a reinforced concrete structure should for the same factor of safety be cheaper than one wholly of steel or wholly of concrete, other things being equal. A given volume of steel costs about fifty times as much as the same volume of concrete, and for the same sectional area steel will carry about thirty times as much load in compression and three hundred times as much in tension as concrete. Thus, for compression only concrete will carry a given load at three-fifths of the cost of steel, whereas for tension it would cost six times as much as steel, so that it can be seen that by suitably combining the two materials so that they act as a composite structure, an economical result can be obtained, and the scientific design of reinforced concrete obtains the most economical proportions and arrangement of the two materials.

PROPERTIES OF CONCRETE.

The properties of concrete vary with its age and with the proportions and quality of the ingredients, and in adopting any figure for safe stresses in design it is necessary to see that the concrete is of the requisite quality and age for which the figures are accepted as satisfactory.

Compression.—The compressive strength of concrete is roughly proportional to the proportion of the cement in the mortar. Fig. 1 shows a diagram plotted from the results of experiments by Mr. G. W. Rafter, of New York. Clean, pure silica sand and Portland cement were used, and the aggregate consisted of sandstone broken so as to pass through a 2-in. ring, containing 37 per cent. of voids when rammed.

The compressive strength increases with age, and Fig. 2 shows on a diagram the results of experiments made at the Watertown Arsenal, U.S.A., in 1899.

Curve *A* is for a mixture of one part of cement, two parts sand, four parts of aggregate; and curve *B* is for a mixture of 1 : 3 : 6. The figures given are for the same brand of cement. It may be taken that for a mixture of 1 : 2 : 4 with high-grade cement, clean, sharp sand, and broken stone or gravel, a safe compressive stress to adopt for bending calculations is 500 lbs. per sq. in. after twenty-eight days.

In this country at present there are few or no local building regulations for reinforced concrete, but many Continental and American towns specify safe stresses.

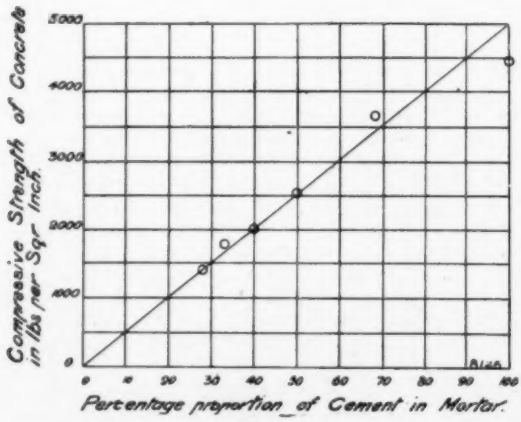


FIG. 1

Tension.—Not nearly so much work has been done on the tensile as on the compressive strength of concrete. The tensile strength depends upon the composition and age, and most authorities agree in taking the tensile strength as one-tenth of the compressive strength of concrete of the same age and composition. M. Considère, one of the leading authorities on the subject, deduced from experiments that, when reinforced, concrete would bear much greater tensile strain without rupture, the reinforcement having the effect of distributing the extension uniformly along the length, but

gave it as his opinion that the concrete when in this extended state would not carry any additional load. Prof. Turneare made some similar experiments, and these seem to discredit Considère's theory. The latter experiments seem to indicate that minute cracks, invisible to the eye but permeable to water, occurred in the overstained concrete, and that test pieces including such cracks were much weaker than those taken between them. Future work will probably throw more light upon this very interesting point. In most of the theories of reinforced concrete it is assumed that the tensile strength of the concrete is negligible and that all the tensile forces are carried by the reinforcement. This will be more clearly explained later in considering beams.

Shear.—The shear strength of concrete is not known very exactly. Indeed, shear strength is a very troublesome thing to determine experimentally, and is always of a somewhat complicated nature, as it involves the compressive and tensile strengths. According to different authorities, the shear strength varies from ·12 to ·2 of the compressive strength. For the composition given in the case of compression, the safe shear stress may be taken as 75 lbs. per sq. in.

Modulus of Elasticity.—This property, which does not enter very much into the design of ordinary structures, is of great importance in reinforced concrete. It is defined as the ratio between the stress per sq. in. and the strain per inch length. The reason why this quantity is of such great importance is that the concrete and steel act together as a composite structure, and so the strains in both materials will be the same under direct load. For a given strain a given stress results, and this stress can be found only when the modulus of elasticity is known. In designing work it is the ratio of the moduli of steel and concrete that we require to know, and not the absolute value of each.

Now, when concrete is compressed, the diagram showing the relation between stress and strain is not straight, and

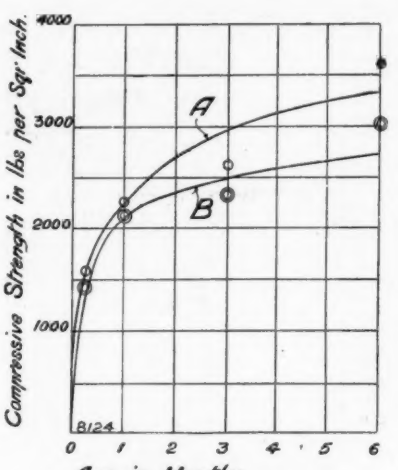


FIG. 2.

therefore it is not quite right to speak of an elastic modulus, because the value changes according to the stress. In compression the value of the elastic modulus for 1 : 2 : 4 concrete varies, according to various experimenters, from about 1,300,000 lbs. per sq. in. to about 4,000,000 lbs. per sq. in., and is smaller for higher stresses. For mild steel the elastic modulus is much less variable, and is about 29,000,000 lbs. per sq. in. The values of the ratio of the elastic moduli for the above extremes are thus 22·3 and 7·25. We shall in future denote this ratio by e. The value adopted in practice varies from 8 to 15, and the latter figure is becoming quite common, and is specified in the recent new building regulations for San Francisco. The importance of this ratio points to the necessity of further work on the subject, and it should be remembered that the best value to use is the one found for the given mixture between the stress limits adopted for the design. The modulus in tension for concrete is not the same as in compression, and experimental results seem to be rather in conflict. In the present article we shall consider only those theories which

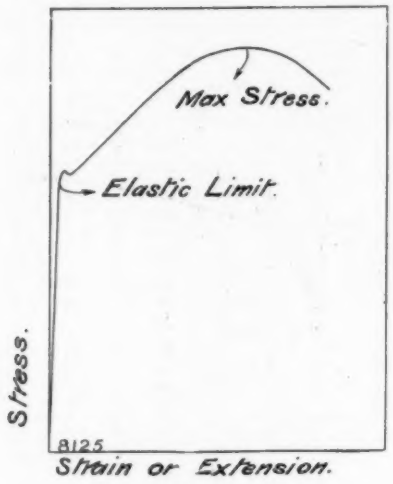


FIG 3.

neglect the tensional resistance of the concrete, and so will give no further information concerning this modulus.

Adhesion between Concrete and Steel.—It is absolutely necessary in a reinforced concrete structure that there shall be a good bond between the concrete and the steel, for the latter will bear its share of the stress only so long as there is no relative movement between the steel and the concrete. Directly such relative movement takes place the tensile stress will come upon the concrete, and cracks will result. To ensure the efficiency of the bond, many of the reinforced concrete systems employ reinforcing bars, which are notched, or twisted, or otherwise provided with mechanical means for ensuring a good bond. With plain round bars the adhesion per sq. in. of the surface of the steel can be found by embedding a length of steel rod in concrete and measuring the force necessary to pull it out. If l is the length embedded and d the diameter, then $\pi d \times l$ is the area of the surface of contact, and if F is the force necessary to pull the bar out of the concrete, and fa the adhesive stress per unit area, then

$$fa = \frac{F}{\pi d \times l}.$$

Here again there is a great variation according to different experimenters, the valve of fa, varying approximately from 150 to 600 lbs. per sq. in., but for the quality of mixture for which figures have been given 75 lbs. per sq. in. is commonly considered as a satisfactory working adhesive stress.

Coefficient of Expansion. A point commonly urged in favour of reinforced concrete construction is that concrete and steel have the same coefficients of expansion, and that there are therefore no internal stresses due to change in temperature. Many authorities do not quite agree with this statement, and state that the coefficients for concrete and steel are 55×10^{-7} and 66×10^{-7} per degree Fahrenheit respectively.

PROPERTIES OF STEEL.

The properties of steel are far less variable than those of concrete

Elastic Limit.—When a steel bar is tested in tension or compression, the strain will be found to be proportional to the stress up to a certain point called the elastic limit. Fig. 3 shows a typical stress-strain diagram for mild steel, the elastic limit occurring at the point indicated. The elastic limit depends upon the proportion of carbon in the steel, and for mild steel may be taken as about 36,000 lbs. per sq. in., but the exact figure should be obtained whenever possible. Now, this quantity, which is rather neglected in ordinary structural work, is of great importance in reinforced concrete, for all the calculations are based on the elastic modulus up to the elastic limit, and as soon as the elastic limit is passed this modulus quickly diminishes and the concrete has to suddenly bear a larger stress in consequence. Safe working stresses for tension in the steel should be therefore taken as a certain proportion of the elastic limit and not of the ultimate strength. The new rules of San Francisco, previously referred to, specify that the working tensile stress shall be taken as one-third of the elastic limit.

For the steel above referred to, this would give a working stress of 12,000 lbs. per sq. in. The strength and other properties of steel in compression may be taken as the same as for tension.

Shear.—The shear strength of steel is roughly about four-fifths of its tensile strength and the working stress for shear may be taken as 10,000 lbs. per sq. in.

Other properties of steel have been given in considering those of the concrete.

REINFORCED CONCRETE UNDER SIMPLE COMPRESSION.

The following note on the strength of reinforced concrete under pure compression will assist in understanding the theory of bending to be given later.

For the simplest case we will take a concrete column reinforced with a central steel core. We must assume that the column is sufficiently short for buckling to be neglected, this commonly being considered as allowable if the length is not more than fifteen times the least diameter. The allowance for buckling is outside the scope of the present article. Suppose that the load carried is W, and the length l, and let the areas of cross-section of steel and concrete be As and Ac respectively. When the load is applied a certain compression per unit length, say x, results (x is total compression divided by l). Further, let the elastic moduli of steel and concrete be Es and Ec and the compressive stresses fs and fc respectively.

Then

$$Es = \frac{fs}{x} \text{ or } x = \frac{fs}{Es} \quad . \quad . \quad . \quad (1).$$

But since there is no slip between the steel and the concrete, x is also the strain in the concrete.

$$\therefore x = \frac{fc}{Ec} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2).$$

$$\therefore \text{ we get } \frac{fc}{Ec} = \frac{fs}{Es}$$

$$\text{or } fs = \frac{Es}{Ec} \cdot fc = e \cdot fc \quad . \quad . \quad (3).$$

Now the load carried by the steel is $fs \times As$ and by the concrete $fc \times Ac$.

$$\therefore \text{ Total load } W = fs \times As + fc \cdot Ac$$
$$= fc \cdot e\,As + fc \cdot Ac$$
$$= fc\,(Ac + e.\,As) \quad . \quad . \quad . \quad (4).$$
$$\text{or} = fs\left(\frac{Ac}{e} + As\right) \quad . \quad . \quad . \quad (5).$$

Thus we see that the reinforced column behaves in the same way as a concrete column of the same length and of area equal to that of the concrete together with e times the area of the steel.

The following numerical example will make this more clear. Fig. 4 shows a column 20 in. square, reinforced with four $1\frac{1}{4}$ in. bars. Required to find the working load if the working compressive stress of concrete is taken as 450 lbs. per sq. in. (A slightly lower figure is usually taken for direct compression than for compression in bending.)

In this case

$$As = 4 \times 1{\cdot}2227 = 4{\cdot}91 \text{ sq. in. nearly}$$
$$Ac = 20 \times 20 - 4{\cdot}91 = 395 \text{ nearly.}$$

Then if

$$e = 15$$
$$W = 450\,(395 + 15 \times 4{\cdot}91) \text{ lbs.}$$
$$= 210870 \text{ lbs. nearly.}$$
$$= 94 \text{ tons nearly.}$$

To get the stress in the steel we see from (5) that

$$fc = \frac{W}{\frac{Ac}{e} + As} = \frac{e\,W}{Ac + e\,As} = \frac{15 \times 210870}{468{\cdot}6}$$

$$= 6{,}730 \text{ lbs. per sq. in nearly.}$$

To get the adhesive stress we may proceed as follows:

Load carried by concrete $= fc \times Ac = 177{,}750$ lbs.
Load carried by steel $= fs \times As = 33{,}100$ lbs.

The difference carried by the adhesion is 144,650 lbs.

Taking the length of the column as

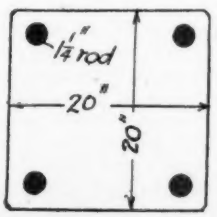


FIG. 4.

24 ft., the area of the adhesive surface is $4 \times 24 \times 12 \times 11 \times 1\frac{1}{4} = 45{\cdot}20$ sq. in.

$\therefore$ Adhesive stress $= \frac{144650}{4520} = 32$ lbs. per sq. in. nearly.

In reinforced columns it is common to brace the bars by spirally wound wire, this adding materially to the strength, but the investigation of the effect of this spiral bracing is somewhat involved and cannot be further considered in this article.

REINFORCED CONCRETE BEAMS.

There are many formulæ for the strength of reinforced concrete beams, such formulæ being deduced from certain assumptions with reference to the distribution of stress in the bent beam. We will consider one of the simplest sets of formulæ, this being in most common use.

When a beam is bent, the cross-section becomes strained, and thus certain stresses are induced, the moment of these stresses being called the moment of resistance, and being numerically equal to the bending moment for the given load sytem to which the beam is subjected.

We will make the following assumptions with regard to the distribution of such stresses and strains:

(*a*) That a plane section of the beam vertical before flexure becomes an inclined plane section after flexure.

(*b*) That the stresses in the concrete and steel are proportional to the strains.

(*c*) That the resultant of all the compressive forces in the concrete will be equal to the total tensile force in the steel, the tensile resistance of the concrete being neglected, and there being no resultant force in the direction of the length of the beam.

Inasmuch as part of the cross-section is in compression and part is in tension, it follows that there must be one portion of the section which is unstrained. This portion is called the *neutral axis*.

We will adopt the following rotation: Ec, Es, e, fc, fs, Ac, As will be used as previously. Consider a rectangular beam of breadth b and depth h.

Let q be the distance from the top of the beam to the centre of the reinforcement.

„ x be the distance from the top of the beam to the neutral axis.

„ v be the distance from the neutral axis to the centre of the reinforcement.

Then Fig. 5 gives the diagram of the strained beam.

In accordance with assumption (*a*) a vertical section $A\ B$ becomes an inclined plane section $A^1\ B^1$, the neutral axis being at the point C.

What we want first to determine is the position of the neutral axis.

Now $A\ A^1$ and $D\ D^1$ represent the maximum strains in the concrete and the steel respectively, and since the line $A^1\ B^1$ is assumed straight, these strains are proportional to their distances from the neutral axis.

$\therefore$ We have $\frac{\text{Max. strain in concrete}}{\text{Max. strain in steel}} = \frac{x}{v}$. (6).

The cross-section of the steel is assumed to be sufficiently small for the strain and stress to be constant over it. But we have seen that max. strain in concrete $= \frac{fc}{Ec}$, and that strain in steel $= \frac{fs}{Es}$.

$$\therefore \frac{fc}{Ec} \div \frac{fs}{Es} = \frac{x}{v}.$$

$$\therefore \frac{fc}{fs} = \frac{x}{v} \cdot \frac{Ec}{Es} = \frac{x}{e \cdot v} \quad \ldots \quad (7)$$

and since $x = q - v$,

$$e \cdot v \frac{fc}{fs} = q - v,$$

$$\text{or } v = \frac{q}{1 + \frac{efc}{fs}} \quad \ldots \quad (8).$$

This determines the distance of the neutral axis from the reinforcement when fc and fs are both known; but this will not always be the case. If the reinforcing bars are of given size, then fs will depend upon that size, and to determine the position of the neutral

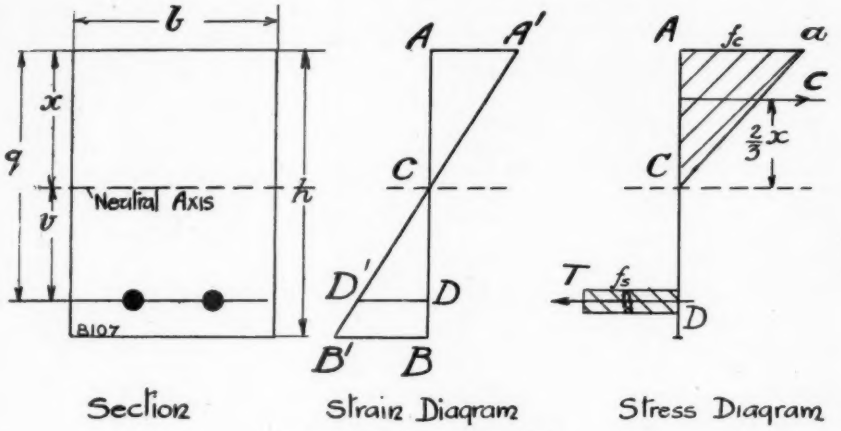


FIG. 5.—REINFORCED CONCRETE BEAMS.

axis, we proceed as follows:—Fig. 5, stress diagram, shows the distribution of stress in the cross-section. Since we have assumed the stress proportional to the strain, the stress diagram for the concrete will be a triangle. It will be seen therefore that the mean compressive stress is $\frac{1}{2} fc$, and since the compression area is $b \times x$, we see that the total compressive stress is $\frac{1}{2} fc\, b \times x$.

As the stress in the steel is assumed uniform, we get that the total tensile stress in the steel is $fs\ As$, and if the beam is subjected to pure bending these must be equal.

$$\therefore fs\ As = \tfrac{1}{2} fc\, b\, .\, x \quad . \quad . \quad . \quad (9).$$

$$i.e., \frac{fc}{fs} = \frac{2\ As}{b \times x}.$$

Comparing this with equation (7) we get

$$\frac{2\ As}{b\ .\ x} = \frac{x}{e\ .\ v}$$

$$\therefore bx^2 = 2\ As\, e\ .\ v \quad . \quad . \quad . \quad (10).$$

but $v = q - x$.

$$\therefore bx^2 = 2\ As\, eq - 2\ As\, e\ .\ x$$
$$\therefore bx^2 + 2\ As\, e\ .\ x - 2\ As\, e\ .\ q = 0.$$

The real solution of the quadratic equation gives

$$x = \frac{As\, e}{b}\left\{-1 + \sqrt{\left(1 + \frac{2\, bq}{As\, e}\right)}\right\} \quad . \quad . \quad (11).$$

Since all the quantities in this expression are given, this fixes the position of the neutral axis.

Moment of Resistance.—We can now comparatively simply find the moment of resistance. The resultant compression acts at the centre of gravity of its triangle.

Therefore the distance between the resultant compressions and tensions is $\frac{2}{3} x + v$.

$\therefore$ if C and T represent these resultant compressions and tensions, we have that the moment of the couple due to the resisting stresses, which is called the moment of resistance, is given by

$$M_R = C\ (\tfrac{2}{3} x + v)$$
$$= \tfrac{1}{2} fc\, bx\ (\tfrac{2}{3} x + v) \quad . \quad . \quad . \quad (12).$$
$$\text{or, } M^R = T\ (\tfrac{2}{3} x + v)$$
$$= fs\ As\ (\tfrac{2}{3} x + v) \quad . \quad . \quad . \quad (13).$$

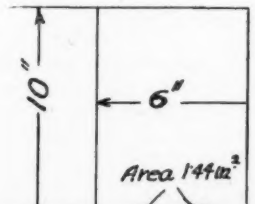


FIG. 6.

and this moment of resistance must be equal to the maximum bending moment due to the loading.

The following numerical example explains the working of these formulæ.

Fig. 6 shows the section of a reinforced beam.

The area of the steel is in this case 1·44 sq. in., and e is taken 15. Then putting the value in the equations we get

$$x = \frac{1{\cdot}44 \times 15}{6}\left\{\sqrt{1 + \frac{2 \times 6 \times 10}{1{\cdot}44 \times 15}} - 1\right\}$$

$$= 4{\cdot}96 \text{ in.}$$

$$\therefore v = 10 - 4{\cdot}96 = 5{\cdot}04 \text{ in.}$$

Then M_R, considering the concrete, is equal to

$$\frac{500 \times 6}{2} \times 4{\cdot}96 \left\{5{\cdot}09 + 3{\cdot}31\right\} = 62{,}000$$

inch lbs. nearly.

The stress in the steel is then

$$\frac{62000}{8{\cdot}35 \times 1{\cdot}44} = 5{,}150 \text{ lbs. per sq. in.}$$

Suppose the span is 10 ft., then the maximum bending moment, if the load is uniformly distributed, is $\frac{W \times 10}{8}$ ft. lbs. where W is the load in lbs.

$$\therefore \frac{W \times 10}{8} = \frac{62000}{12} \text{ or } W = \frac{62000 \times 8}{12 \times 10} =$$

4,130 lbs. nearly.

Thus the safe uniform load for the given section and span is 4,130 lbs., including its own weight.

It will be seen from the stress in the steel that the amount of reinforcement (2 per cent. of the section) is more than it need have been, and for each theory of stresses there exists an economical proportion of steel to concrete. The above treatment is necessarily incomplete, but it should give the reader sufficient acquaintance with the subject to be able to study with profit the text-books which deal in detail with reinforced concrete. Among such books should be mentioned Marsh's "Reinforced Concrete" and Buel and Hills' "Reinforced Concrete Construction."

Practical Pyrometry.

By ROBERT S. WHIPPLE.

It would be difficult to mention many industrial operations that do not involve, during some stage or other, an accurate measurement of temperature. To the engineer, power station manager, foundry operator and metallurgist the judgment of temperature has become of the first importance, as upon it depends the maintenance of efficiency at its highest possible value or the perfection of the material under treatment. Guess-work —concomitant with costliness—is now being gradually replaced by scientific thermometry, and manufacturers are realising the assistance that the physicist is capable of affording them in the vital matter of accurate high temperature measurement. The Féry Radiation Pyrometer has brought the latter within the reach of industrial concerns, and improvements in resistance thermometry have simplified and reduced adjustments to a minimum. Few have a wider knowledge of or have contributed more to the progress that has been made than Mr. R. S. Whipple, of the Cambridge Scientific Instrument Society, whose contributions to the Proceedings of the Western Society of

Engineers, Chicago,* reproduced below, forms a valuable exposition of the state of the science.

Although we are, perhaps, apt to laugh at the very rough methods adopted by our predecessors for the measurement of temperature, it cannot be denied that the accurate measurement of temperature is still a problem of considerable difficulty. Temperature is not a measurable quantity in the strict sense of the term. To measure a length or a mass is to count how many times it is necessary to take a given body chosen as a unit (metre or gramme, as the case may be) in order to obtain a system equivalent, either as a length or mass, of the body in question. The possibility of such a measurement assumes the existence of two laws—that of equality, and that of addition. Temperature obeys the first of these laws—two bodies in temperature equilibrium with each other. The other law is entirely lacking. You cannot by placing together several bodies at one temperature realise a system equivalent, from the point of view of exchange of heat, to a body at a different temperature.

Many scales of temperature have been proposed, but the gas scale is the one now universally adopted, and readings obtained by any type of thermometer—electrical, expansion or optical—are reduced to temperatures on the gas scale. The gas scale has been adopted as the standard scale of temperature—firstly, because gas of the same purity can be reproduced at any time; secondly, the dilatation of the gas, which defines the scale of temperature, is sufficient for accurate measurement; and thirdly, the scale is practically identical with the thermodynamic scale.

Although the scale of the gas thermometer has become the standard of reference, yet, fortunately, we are not compelled to use the gas thermometer in every-day life. We do not employ an elaborate gas thermometer, with its adjuncts of telescopes, microscopes, and standard barometer, every time we wish to measure a temperature; but we use a thermometer which has been carefully standardised at certain known temperatures. Fig. 1 illustrates one of the gas thermometers in use at the Bureau des Arts et Metiers, Paris, and shows clearly that the instrument is rather a complicated piece of apparatus. Dr. Arthur L. Day has succeeded in eliminating various sources of error which have previously been present in these thermometers, and I think that perhaps the Carnegie Institute at Washington now possesses the most accurate gas thermometer in the world.

Thermometers, and under this name I include pyrometers, are generally standarised by means of fixed points of fusion and ebullition determined by the gas thermometer. It is, perhaps, for this reason that many of the discrepancies in high temperature thermometry have arisen. The actual precision of the high temperature measurements depends on the degree of accuracy to which these fixed points are known. It has at present been found impossible to determine many of these directly on the gas thermometer, as even the platinum-iridium bulb of the gas thermometer becomes porous at extremely high temperatures. High temperature thermometry is badly handicapped through the scarcity of materials capable of being made into a thermometer bulb and of standing high temperatures. Platinum—the great stand-by—has been shown by Sainte-Claire-Deville, and others, to be very permeable to hydrogen—a gas which is generally present where combustion is incomplete. Fortunately, platinum, even when red hot, is practically impervious to all other gases; so that if nitrogen is employed as the gas whose volume we are measuring, and the platinum is suitably protected from hydrogen, accurate observations may be made. Porcelain must be glazed to ensure non-permeability, and the glaze cannot be considered impermeable above 1,100° C. Water vapour passes comparatively rapidly through unglazed porcelain.

* Vol. XII., No. 2.

In passing, one cannot help being struck with the inter-dependence of all branches of scientific work. At the first thought it would occur to one that the accurate determination of the value of the metre would be the means of producing the most accurate thermometry the world has seen; yet so it has been. To determine the length of a standard bar it is essential that its temperature should be known accurately; to measure the temperature accurately, the constants of the thermometer employed must be known to a high degree of precision, and these can only be obtained from an elaborate system of comparators, gas thermometers, &c. Thus the preliminary work on the measurement of the metre produced the masterly work of Dr. Ch. Guillaume on the mercury thermometer and his valuable treatise "Thermométrie de Précision."

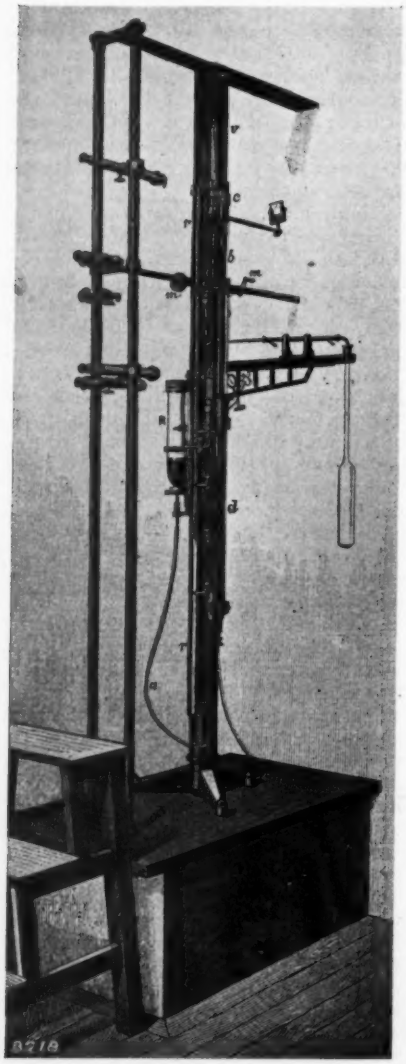


FIG. I.—GAS THERMOMETER.

I cannot here enter into details of the construction and working of a gas thermometer, and would refer those who are especially interested to Dr. Guillaume's book previously mentioned, or to Dr. Burgess's translation of M. Le Chatelier's book, "High Temperature Measurements." I must acknowledge my indebtedness to the latter book for some of the facts mentioned in this paper.

As previously stated, the gas thermometer, although invaluable from the strictly scientific point of view, is practically useless as a tool in every-day life. It will be well, therefore, to summarise roughly the various means of measuring temperature in general use, and then to treat these methods more fully in detail with their particular applications.

Dr. Charles Chree, F.R.S., in some valuable "Notes on Thermometry," published in the Philosophical Magazine for March, 1898, makes the statement that "the ideal mercury thermometer is one which accommodates itself at once and completely to the temperature it is for the time being exposed to, and which when exposed to a given temperature, supplies an invariable reading."

I think there could not be a better definition of what is required from any form of thermometer.

Expansion Thermometers. — Although the gas thermometer is essentially an

TYPES OF THERMOMETERS IN GENERAL USE.

		Type.	Range in degrees Centigrade over which they can be used.
Expansion	Those depending on the change in volume or length of a body with temperature.	Gas	0° to 1000°
		Mercury, Jena glass and nitrogen	—40° to 500°
		Glass and spirit or petrol	—200° to +40°
		Unequal expansion of metal rods	0° to 500°
		Contraction of porcelain	0° to 1800°
Transpiration and Viscosity	Those depending on the flow of gases through capillary tubes or small apertures.	The Uehling	0° to 1600°
Thermo-electric	Those depending on the electromotive force developed by the difference in temperature of two similar thermo-electric junctions opposed to one another.	Galvanometric	0° to 1600°
		Potentiometric	0° to 1600°
Electric Resistance	Those utilising the increase in electric resistance of a wire with temperature.	Direct reading on indicator or bridge and galvanometer	0° to 1200°
Radiation	Those depending on the heat radiated by hot bodies.	Thermo-couple in focus of mirror	0° to 10,000°
		Bolometer	0° to 10,000°
Optical	Those utilising the change in the brightness or in the wave-length of the light emitted by an incandescent body.	Photometric comparison	0° to 2000°
		Incandescent filament in telescope	0° to 2000°
		Nicol with quartz plate and analyser	0° to 2000°
Calorimetric	Those depending on the specific heat of a body raised to a high temperature.	Copper or platinum ball with water vessel	0° to 1500°
Fusion	Those depending on the unequal fusibility of various metals or earthenware blocks of varied composition.	Alloys of various fusibilities.	0° to 1980°

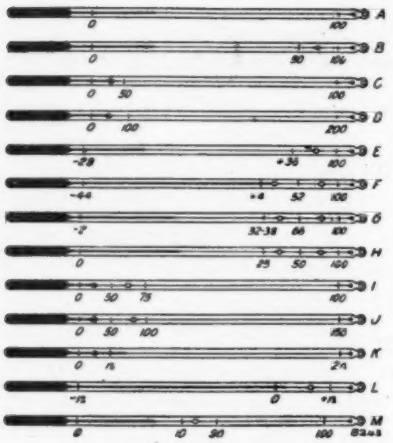


FIG. 2 — GROUP OF STANDARD MERCURY THERMOMETERS.

expansion instrument, yet the mercury in glass thermometer must be considered as the expansion instrument *par excellence*. Many of us know how far the mercury thermometer, as generally used, falls short of Dr. Chree's ideal, but I think few of us realise how near Dr. Guillaume has brought us to that ideal. It is now possible, thanks to his work, to measure temperature with a mercury thermometer, to an accuracy of 0.001° C.

It is sad to think how far we in America and Great Britain have been behind French and German practice in the construction of accurate mercury thermometers; more especially when it is borne in mind that Kew standards, as made under the direction of Balfour Stewart and Welsh, were for many years the standards of the world. I can only account for it by the fact that we were standing still whilst the National Physical Laboratories of France and Germany were developing the construction and materials of their thermometers. This reproach has now been removed, and you, with your Bureau of Standards under the far-seeing direction of Prof. Stratton, and we, with our National Physical Laboratory under Dr. Glazebrook, are doing work which will take rank with that of the Continental National Laboratories.

There is no necessity for me to explain the details of construction of a mercury thermometer to you. Fig. 2 illustrates a group of Standard thermometers capable of the highest precision work. It will be noticed that all the thermometers have the two fundamental points of zero and 100° C. engraved upon their stems for purposes of standardisation. The enlargements in the capillary bore are made in order that a much more open scale of degrees may be used than would be otherwise possible; it necessitates, however, the employment of several thermometers to obtain the complete scale.

Now that nitrogen is being introduced into the stem of the thermometers above the mercury they may be used up to temperatures as high as 500° C. Glass thermometers filled with petrol may be used to measure temperatures as low as —200° C. Fig. 3 is the reproduction of a record of air temperature obtained with a mercury thermometer and recorded automatically on a sheet of paper mounted on a clock-driven drum. The thermometer is so mounted that with a change of temperature the position of a style relatively to the paper is altered, these alterations being automatically recorded. The details of the recording mechanism will be explained when describing the thread recorder further on in this paper.

An expansion thermometer of general interest, is the one in which temperature is measured by the unequal expansion of two materials, such as steel and porcelain or graphite.

A graphite rod is placed at the bottom of a closed steel tube, a small steel tube being connected to the upper end of the graphite rod. By means of the various simple mechanical movements the differential expansion of the two rods is indicated on a dial. These thermometers are useful up to temperatures of about 500° C., but cannot be relied upon for measurement of an accuracy higher than 10 per cent.

Transpiration and Viscosity. — The

Uehling and Steinhart thermometer is based on the resistance to the flow of gases through two apertures. One of these apertures is exposed to the high temperature to be measured, so that the gas after entering the aperture has obtained this temperature. The other aperture is maintained at a constant temperature generally 100° C. Air under constant head is drawn through the two openings. Two manometer tubes are connected to the chambers into which the apertures open, and an inverted bell jar floating in mercury records the differences in pressure between them. These differences in pressure can be readily converted into the difference in temperature between the gases entering the two apertures.

Thermo-Electric.—I now come to what I may call the third group, the thermo-electric thermometers, in which is measured the electromotive force developed by the difference in temperature of two similar thermo-electric junctions opposed to one another. Becquerel was, as far as is known, the first to use this method of measuring high temperatures (1830). He used a platinum-palladium couple. His son, Edmund Becquerel, was the first to realise the importance of using a high resistance galvanometer with a thermo-couple. The electromotive force is a function of the temperature, and as it is the current strength that is measured, it is important that the resistance of the whole circuit should be as nearly as possible constant; that is to say, the change in resistance of the couple itself should be small as compared with the change in the rest of the circuit. For some time the thermo-electric method was regarded with suspicion, Regnault having observed such irregularities in the couples in use that he condemned the method unreservedly.

Chatelier showed that very few combinations of wires make satisfactory couples. Iron, nickel, palladium, and their alloys are absolutely unsuited for the measurement of high temperatures, since, when heated, these wires give rise to parasitical currents which may be relatively intense. He found that platinum and its alloys with iridium and rhodium are, fortunately, free from these faults. Of all the couples, those consisting of platinum and an alloy of platinum with 10 per cent. of rhodium are the most durable for use at extremely high temperatures. On the other hand, a platinum and platinum 10 per cent. iridium couple gives a larger electromotive force, and therefore a more open scale.

Some recent works by Holborn and others have shown that the change (decrease) in the e.m.f. and two Pt. and Pt. Ir. (10 per cent. Ir.) thermo-couples due to glowing at 1,100° C. for eight hours amounted to 6 per cent. and 14 per cent., while the change (increase) in the e.m.f. of a Pt. and Pt. Rh. (10 per cent. Rh.) thermo-couple, exposed to similar conditions, was only 0·5 per cent.

Some exceedingly interesting work by

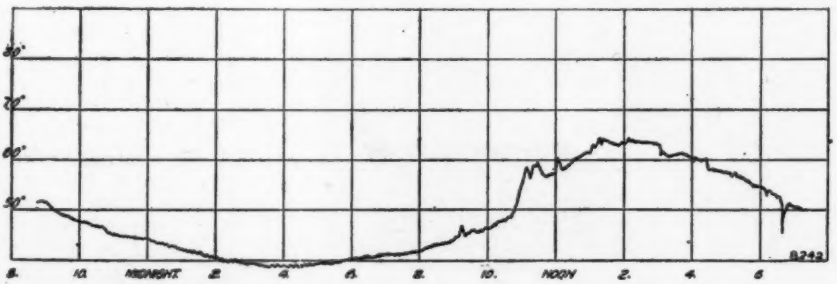


FIG. 3.—REPRODUCTION OF A RECORD OBTAINED WITH A RECORDING MERCURY THERMOMETER.

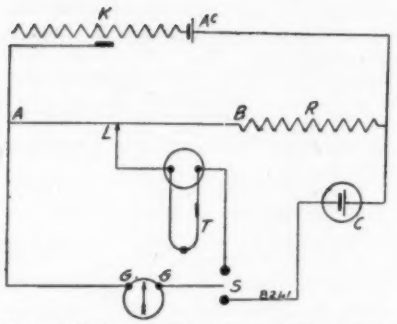


FIG. 4.—DIAGRAM SHOWING METHOD OF DETERMINING TEMPERATURES WITH A THERMO-COUPLE AND POTENTIOMETER.

Dr. W. P. White,* of the Carnegie Institute, shows that the iridium sublimes slowly at temperatures above 1,200° C. and enters and contaminates the platinum side of the thermo-element. The effect of this contamination is to make the element read too low. Iron vapour has also been shown to have the same effect. It has been known for a long while that unprotected platinum, when exposed to furnace gases, deteriorated rapidly, but this deterioration has been put down to the action of the furnace gases rather than to the volatile metals. I feel there is still room for further research on the deterioration of thermo-couples, but all the results show the importance of protecting the couples with glazed porcelain tubes.

Two methods are generally employed to measure the electro-motive force of a thermo-couple: the potentiometric or the method of compensation, and the galvanometric. The first method is rather cumbrous for general workshop use, but it is undoubtedly the more accurate. It consists in balancing the e.m.f. given by the unequally heated junctions against the drop of potential between two points in a circuit produced by an accumulator or other steady battery. A cadmium cell is arranged for reference as the standard of e.m.f. This method has the advantage of avoiding any error due to the resistance of the thermo junction itself or the leads connecting it to the potentiometer. The arrangement of the apparatus is shown in Fig. 4. A slide wire of known resistance R, and rheostat K; an accumulator Ac being arranged to produce a steady current through the circuit. One terminal of the galvanometer, G, is connected to one end of the slide wire, and the other G, to a two-way switch S, one contact of which is connected to the standard cell C, the other to the thermo-couple T.

The current in the circuit is adjusted by the rheostat until there is a fall of potential, say 30 millivolts, along the slide wire. The slide wire contact is then shifted until a balance is obtained, when the e.m.f. of the thermo-couple is read off on the scale. The scale is sometimes arranged to read directly in temperatures.

The galvanometric method is simplicity itself, the cold ends of the thermo-couple wires being connected directly to the galvanometer terminals. If the resistance of the circuit is constant, the deflections will be proportional to the electromotive force. The majority of direct reading instruments consist of a sensitive D'Arsonval galvanometer, the coil of which either carries a mirror reflecting a spot of light on to a scale or a boom pointing to a scale. The galvanometer scale is divided in millivolts and degrees centigrade; Fig. 5 shows two types of the

* *Physical Review*, December, 1906.

FIG. 5.—DIRECT READING GALVANOMETER FOR USE WITH THERMO-COUPLES.

galvanometers very frequently used for this purpose.

The advantages of the galvanometric method are portability and simplicity; the disadvantages, closeness of scale, and the fact that an error is introduced by the variation in resistance of the couple.

The potentiometric method has the advantages of an open scale, and that no error is introduced by the resistance of the couple. The only serious disadvantage is the fact that the apparatus must be worked in a laboratory, and requires a trained observer.

A simple form of recorder which may be used with thermo-electric couples is one to which the name "Thread Recorder" has been given. In it the galvanometer pointer *A*, Fig. 6, is depressed every minute by a guillotine *D* on to an inked thread *G*, which is forced against the paper wrapped round the drum *C*, leaving a small ink mark behind on the paper. The ink on the thread is renewed by means of a simple winding mechanism. This method of recording gives rectangular co-ordinates and entirely prevents the blotting or smudging of the record.

The clockwork mechanism can be made to depress two or more galvanometer booms simultaneously, the various galvanometers being connected to different thermometers. Fig. 7 illustrates an instrument for taking four records, the records obtained are entirely independent of each other, and the thermometers may be working over widely different ranges. Fig. 8 is a reproduction of a record obtained with a platinum and platinum-rhodium couple used in conjunction with a thread recorder; Fig. 9 is interesting as a record of the temperature of the flue of a small furnace obtained with an inexpensive thermo-couple, copper-constantin.

Electric-resistance Thermometers. — The electric-resistance thermometer was first proposed by Sir William Siemens in the

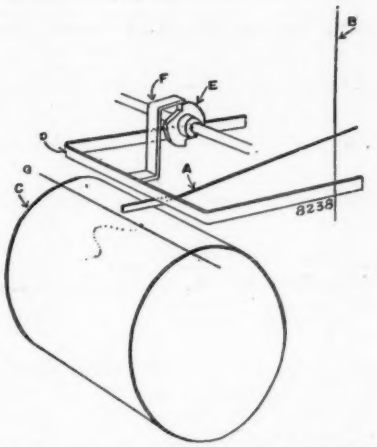


FIG. 6.—ESSENTIAL PARTS OF A THREAD RECORDER.

Bakerian Lecture of 1871, and it immediately came into general use in metallurgical work. Unfortunately, it was found that the pyrometer did not satisfy the fundamental criterion of always giving the same indication at the same temperature, and it was rather severely condemned by a committee of the British Association in 1874, who showed that these changes in resistance were due to chemical alteration in the platinum and defective contacts between the fine wire of the coil and the comparatively heavy conducting leads.

In 1886 Professor Callendar showed

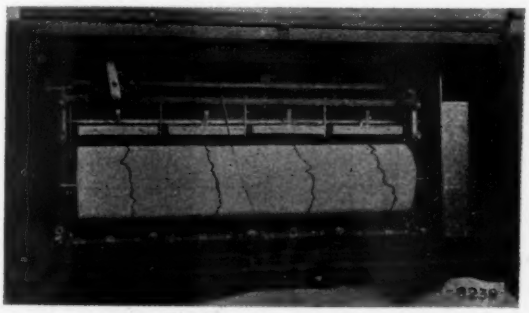


FIG. 7.—RECORDING INSTRUMENT FOR TAKING FOUR RECORDS.

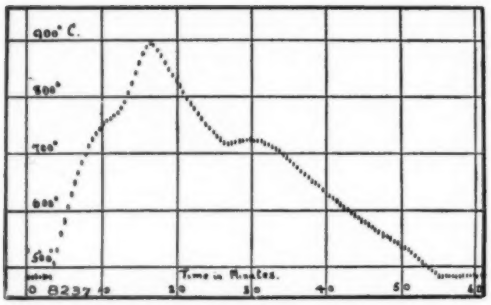


FIG. 8.—RECALESCENCE POINT ATTAINED WITH A PLATINUM AND PLATINUM-RHODIUM COUPLE AND PATENT THREAD RECORDER.

that if the platinum is supported on a mica frame, in section that of a cross with equal arms, there is perfect insulation without any cause of alteration. He also showed that all joints in the wires should be made by fusion. Metallic solderings are volatile and attack platinum, and screw joints become loose. I cannot enter into a description of the classical work of Professor Callendar on this subject, but would refer anyone interested to a paper published by him in the *Philosophical Magazine*, February, 1899, entitled "Notes on Platinum Thermometry," which gives an excellent summary of his work. The results of his researches—and they have since been confirmed by many workers—show that the platinum resistance thermometer, if protected from strain and contamination, is practically free from zero changes over a range of 0 to 1,200° C., and that it always gives the same indication at the same temperature. He also showed that different platinum wires agreed very closely in giving the same value of any temperature on the platinum scale, although they differed considerably in the values of their temperature co-efficients.

Professor Callendar pointed out that if R_0 denote the resistance of the spiral of a particular platinum thermometer at 9°, and R_1 its resistance at 100°, we may establish for the particular wire a temperature scale, which we may call the scale of platinum temperatures, such that, if R be the resistance at any temperature on the air scale, the temperature on the platinum scale will be $\frac{R - R_0}{R_1 - R_0} \times 100$. For this quantity he employs the symbol pt, its value depending on the sample of platinum chosen. In order to reduce temperatures on the platinum scale to the gas scale, it is necessary to know the law connecting T and pt. They are, of course, identical at 0° and 100°, and experiment has shown that the formula

$$T - pt = \Delta \left[\left(\frac{T}{100} \right)^2 - \frac{T}{100} \right]$$

expresses the curve of the relationship between them in other parts of the scale. The value of Δ depends on the purity of the platinum wire used; it can be obtained from observations at three

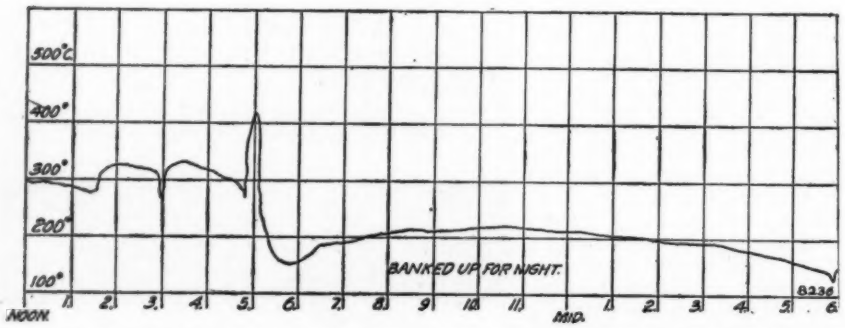


FIG. 9.—TEMPERATURE OF FLUE. RECORD ATTAINED WITH COPPER COUPLE AND THREAD RECORDER.

known temperatures. A table of corrections is used to convert temperatures on the platinum scale to those on the gas scale, or the instrument used with the thermometers may be read directly on the gas scale.

As now constructed, the *platinum resistance* thermometer consists of a fine platinum wire wound on a mica frame connected by means of stout copper or platinum leads to terminals in the head of the thermometer. Two similar leads, but unconnected to the coil, pass through the whole length of the thermometer, and act as compensating leads. By this means no error is introduced by the variation of the temperature of the wires connecting the thermometer with the indicator or recorder. The diagram, Fig. 10, explains the general arrangement for the use of Callendar and Griffiths' resistance thermometer. The thermometer coil forms one arm of the bridge, while the compensating leads and the balancing coils form the opposite arm; a pair of equal ratio arms are generally used. The resistance of the thermometer varies with the temperature, the resistance of bridge-coils and bridge-wire being adjusted so that no current passes through the galvanometer at the moment of taking the temperature. The coils and bridge-wire have been calibrated in terms of temperature.

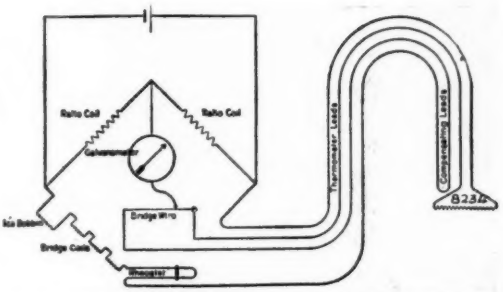


FIG. 10.—DIAGRAM SHOWING METHOD OF MEASURING TEMPERATURE WITH A CALLENDAR AND GRIFFITHS RESISTANCE THERMOMETER.

If temperature measurements are to be made with a resistance thermometer to a high degree of accuracy, a specially designed "Wheatstone" bridge and a sensitive galvanometer must be employed. This arrangement, however, is too cumbrous for general commercial use, and I have designed a bridge, Fig. 11, which is a modification of one invented by Professor Callendar and Principal Griffiths, in which the temperature values are read directly in degrees Centigrade, and rapidly-varying temperatures may be followed. The instrument is especially useful for measuring the temperatures of boiler flues, general testing and annealing work, &c.

Dr. Edwin F. Northrup has designed an ingenious instrument which he calls a *ratiometer*, in which the temperature measurements are made directly on a scale, no manipulative action being required on the part of the observer.

In Fig. 12 is shown the method of connecting an indicator in turn, by means of a switchboard, with a large number of thermometers distributed throughout a cold storage warehouse.

The construction of some typical resistance thermometers is shown in Fig. 13. The platinum resistance coil

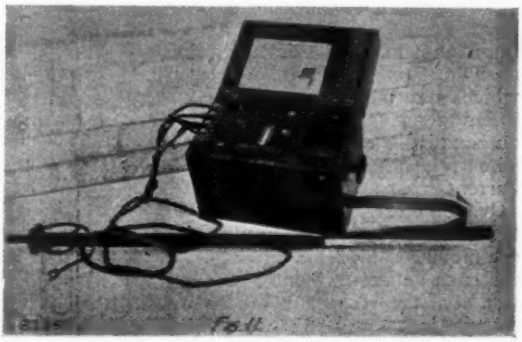


FIG. 11.

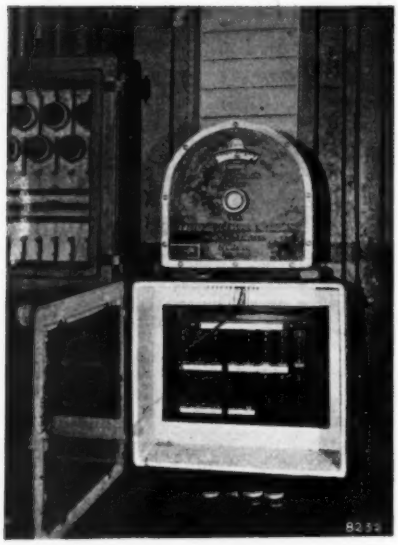


FIG. 12.

is seen at the bottom of the porcelain or steel tube, the coil being connected to the stouter platinum leads. In the annealing furnace type of thermometer (the thermometer on the right, Fig. 13) the porcelain tube is protected by an easily renewable heavy steel sheath.

Professor H. L. Callendar has designed a recording instrument for use with resistance thermometers. It consists of a "Wheatstone" bridge in which the movement of the slider along the bridge-wire is automatically effected by delicate relays worked by the current passing through the galvanometer between the bridge arms. According as the moving coil of this galvanometer is deflected in one direction or the other, a relay circuit is connected through one or other of two electromagnets. Each of these magnets is mounted on a clock, the movement of which is prevented by a brake. When the current energises a magnet, this brake is lifted, allowing the clockwork to revolve. The clocks are connected by differential gearing with a recording pen, which is pulled in one direction or the other, according as the brake is lifted from the corresponding clock. The bridge slider moves with the pen and tends to restore balance.

In Fig. 14 is illustrated the latest commercial form of the recorder; Fig. 15 showing the electrical connections.

The uses to which a satisfactory recorder can be put are almost innumerable. In Fig. 16 two recalescent curves are produced; one record *A*, being characteristic of a mild grade of steel (0.35 per cent. carbon), the other *B*, of a finer steel. A comparison shows clearly the value of such records in

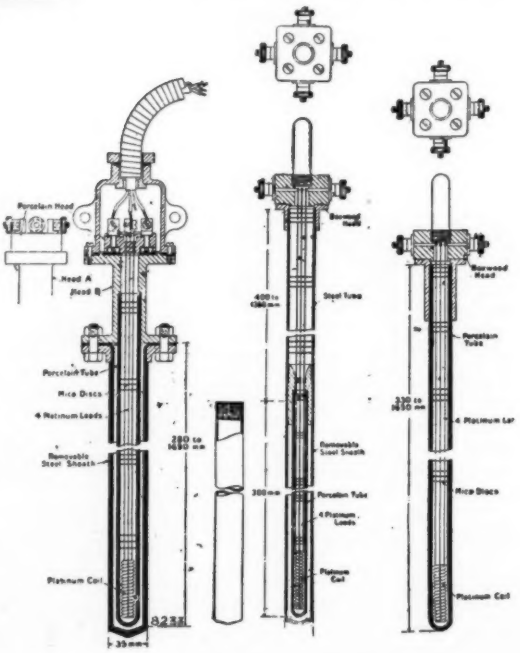


FIG. 13.—TYPES OF CALLENDAR AND GRIFFITHS' RESISTANCE THERMOMETER.

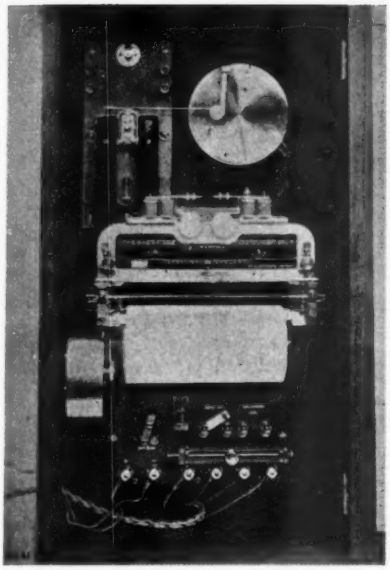


FIG. 14.—LATEST TYPE OF CALLENDAR RECORDER.

discriminating between different qualities of steel.

On every hand we hear of the "heat treatment" of steel, and anyone who has had anything to do with annealing knows the difficulty of maintaining the ovens or furnaces at a constant temperature. The fireman will go to sleep, and will swear that he was awake the whole night through, and in many cases will aver still more strongly that the correct temperature was maintained all the time, the master only learning a few days later from the tests on the material how badly the furnace had been fired. The record Fig. 17 has been kindly given by a firm who employ several of these recorders, and it explains how they have overcome the difficulty. The difference in the firing between the two men—the old experienced hand and the new man, who fires more frequently—is very striking.

Resistance thermometers can be placed at a considerable distance from the reading instrument, and for this reason they have been found useful for measuring temperature of the soil and the temperature of cold stores.

I will now give some instances where resistance thermometers are being used for more strictly scientific work. The first case is, perhaps, one of the most important. Messrs. Heycock and Neville, whose work on the determination of the melting points of metals is so well known, have recently been investigating the behaviour of the copper-tin alloys. This important research, in which many different alloys were included, was carried out by means of these thermometers, and a Callendar electric recorder. Fig. 18 is reproduced

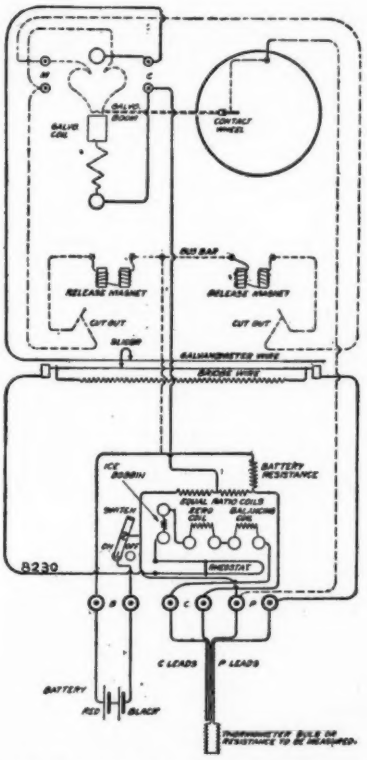


FIG. 15. DIAGRAM OF ELECTRICAL CONNECTION CALLENDAR RECORDER.

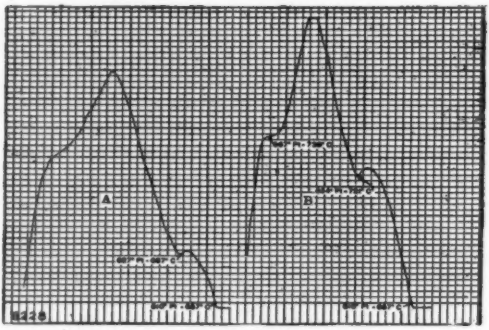


FIG. 16.—TWO RECORDS OBTAINED WITH A RESISTANCE THERMOMETER AND CALLENDAR RECORDER. THE RECALESCENT POINTS ARE WELL MARKED: ONE RECORD (A) BEING CHARACTERISTIC OF A MILD GRADE OF STEEL (0·35 PER CENT. CARBON), THE OTHER (B) OF A FINER STEEL (0·9 PER CENT. CARBON).

from this paper, and shows clearly the marked influence in the freezing point of the alloy made by slightly altering its composition.

The next example will show how extremely small a resistance thermometer may be made. The illustration, Fig. 19, is taken from Callendar and Nicholson's paper on the "Law of Condensation of Steam." The thermometer was fixed in the piston rod of a steam engine, and its temperature read by means of a cycle contact-maker, bridge and galvanometer. A record obtained with a similar thermometer inserted in the cylinder cover is reproduced in Fig. 20. The most striking feature of the curve is the great superheating shown at the end of the compression.

Professor Howard T. Barnes has published some exceedingly interesting results of temperature measurements made

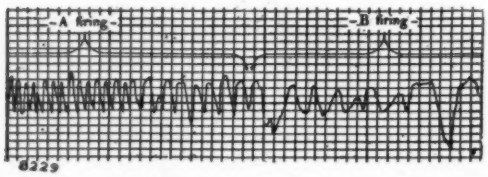


FIG. 17.—ANNEALING FURNACE RECORD. THE DIFFERENCE IN THE FIRING OF THE TWO MEN (A AND B) IS INTERESTING. THE TEMPERATURE IS ABOUT 700° C. EACH SPACE IN THE VERTICAL CORRESPONDS TO FOUR CENTIGRADE DEGREES.

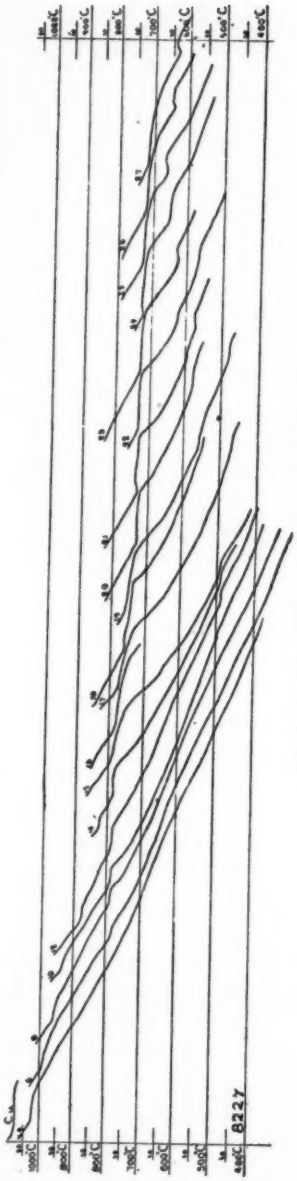


FIG. 18.—COOLING CURVES OF COPPER TIN ALLOYS.

with resistance thermometers in the St. Lawrence River. His measurements were made with a pair of differential thermometers, and the values obtained could be relied upon to 0·0001° C.

The observations obtained were the means of satisfactorily explaining the formation of anchor ice. In the same paper Dr. Barnes mentions the fact that he is "successfully operating a thermometer placed nearly a mile away from the place of observation.

Heat Radiation and Optical Thermometers.—Many workers have endeavoured to evolve a pyrometer that would measure the temperature of a source of heat without the necessity of inserting a "poker," as I believe you, on this side of the water, call the ordinary pyrometer.

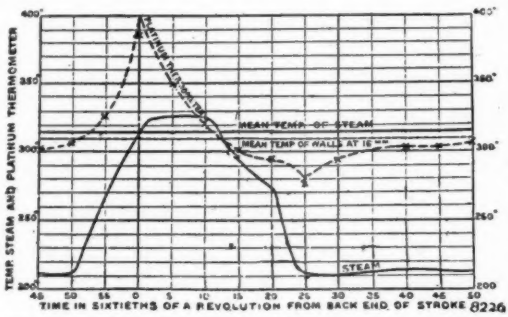


FIG. 20.—RECORD OF THE CHANGES IN TEMPERATURE OF AN ENGINE CYLINDER DURING THE STROKE.

Taking optical pyrometers first, I think that on the whole the so-called absorption, one invented by Professor C. Fèry, is the most successful. It is an improved form of the optical pyrometer of Le Chatelier, and has been found useful for measuring the temperature of incandescent filaments and other extremely hot but small bodies.

It consists essentially of a telescope, *D*, *B* (Fig. 21), which carries a small comparison-lamp *E*, attached laterally. The image of the flame of this lamp is projected on a mirror *F*, at 45 deg. placed at the principal focus of the telescope, the mirror being silvered only over a narrow vertical strip (*a*, *b*, Fig. 21a).

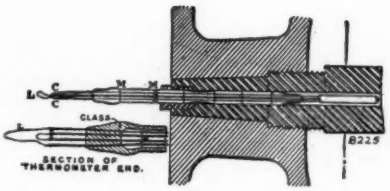
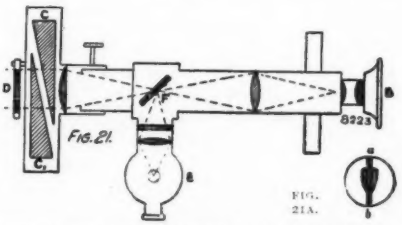


FIG. 19.—SECTION OF PISTON SHOWING PLATINUM THERMOMETER.

The telescope is focussed on the object the temperature of which it is desired to measure, the object being viewed on either side of the silvered strip. A pair of absorbing glass wedges (*C* and C_1) are placed in front of the objective of the telescope, and these wedges are moved laterally by means of a micrometer screw until the light from the object under observation is made photometrically equal to that emitted by the standard lamp. An auxiliary dark glass *D* is also fitted to enable the instrument to work over a higher range of temperature. A table provided with the instrument converts the readings obtained by the scale and micrometer into degrees Centigrade. Fig. 21a shows the telescope focussed on a small crucible, the narrow silvered strip being clearly shown. The instrument designed by Professor Wanner has also been successful. Instead of using monochromatic light as in the case of the Fèry and Chatelier Optical Pyrometer, the light is spread out into a spectrum by a direct vision spectroscope, and a small region in the red is used (Fig. 22). The working



FIGS. 21 AND 21A.—DIAGRAMMATIC ARRANGEMENT OF A FÈRY ABSORPTION PYROMETER.

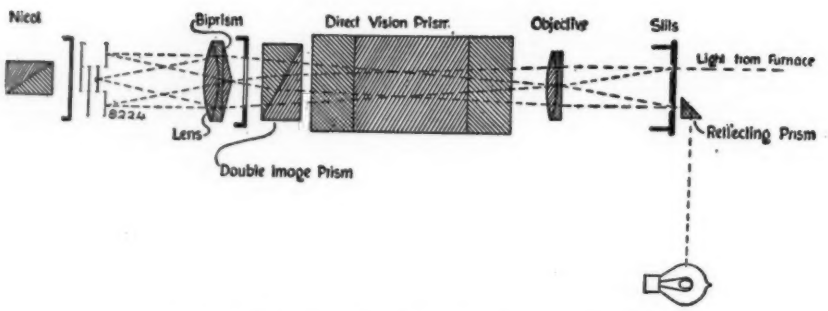


FIG. 22.—DIAGRAM OF OPTICAL ARRANGEMENT OF WANNER PYROMETER.

standard source of light is a small incandescent lamp. The method of reducing the two fields of light from the hot body and the electric light respectively to the same intensity, is first to polarise them in planes at right angles to each other, and then the intensity of each can be varied by viewing them through a Nicol's prism, which can be rotated. This angular rotation of the "Nicol" is then a measure of the intensity of the light, and therefore of the temperature. The incandescent lamp can be standardised against an amyl-acetate flame. Owing to the loss of light in the optical system of the pyrometer, the lower limit of temperature measurement is about 900° C.

In Mesurè and Nouel's Pyrometer Telescope an attempt is made to control temperatures by taking advantage of the rotation of the plane of polarisation of light by passing through a quartz plate, cut perpendicular to its axis. The angle of rotation is directly proportional to the thickness of the quartz, and approximately inversely proportional to the square of the wave length. In general the field of view will be coloured, and by turning the analyser, the colour observed will change because the light, all polarised in the same plane, emerging from the first "Nicol" is polarised by the quartz in various planes depending on the wave length, so that the angle between the two "Nicols" determines the colour that will be seen. This instrument has the advantage over others; it has an auxiliary apparatus, but it lacks sensibility.

An ingenious optical pyrometer has been designed by Holborn and Kurlbaum, working at the Physikalische-Technische Reichsanstalt. An incandescent filament, *L*, Fig 23, is placed on the focus of the eye piece of a telescope, and by means of an object-glass an image of the source of heat is thrown into the same plane. The current passing through the filament is regulated by means of a rheostat until the filament is no longer visible on the image of the source of heat, when both sources of light will have the same intensity.

The Morse gauge is a simplified form of the same thermometer. The most successful radiation pyrometer is that invented by Professor C. Fèry, of the "Ecole de Physique et de Chimie," Paris. The radiation which emanates from a hot body, or which passes out through an observation hole in the wall of a furnace, falls upon a concave mirror, *M*, Fig. 24, and is thus brought to a focus. In this focus is a thermo-electric couple, *D*, whose temperature is raised by the radiation falling upon it; the hotter the furnace, the greater the rise in the temperature of the couple.

The electro-motive force generated by the couple actuates a sensitive galvanometer, the scale of which is based upon the Stefan-Boltzman radiation law which expresses the relation between the temperature of a body and the amount

of radiant energy which it emits, viz., that "The radiant energy emitted by a black body is proportional to the fourth power of the absolute temperature of the body."

The arrangement of the instruments is such that they are uninfluenced within wide limits, by the size of the hot body or observation hole on the one hand, or on the other by the distance which separates them from the hot body or furnace. Fig. 25 is a reproduction of a record of the temperature of a steel annealing furnace, and Fig. 26 of the temperature of a pottery "Biscuit" kiln. These records are especially interesting when it is considered that no part of the instrument was inserted into the source of heat.

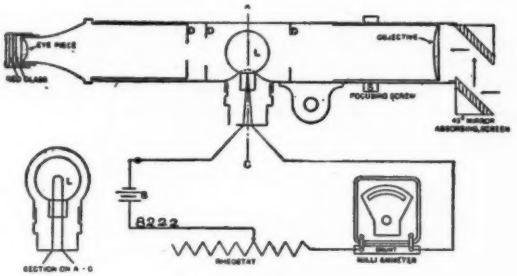


FIG. 23.

Professor Langley designed a radiometric apparatus under the name of a bolometer, which has since been largely developed by Professor Callendar for measuring heat radiations, more particularly solar radiations. It consists of a differential pair of flat platinum thermometers, one blackened, and the other bright placed side by side in the same horizontal plane in a hermetically sealed glass vessel. The difference of temperature between the two, which is automatically recorded on a Callendar electric recorder, is approximately a measure of the intensity of the vertical component of the radiation to which they are exposed. It has already been shown with these instruments that the heat received by reflection from the sky under certain conditions may amount to more than 40 per cent. of the whole vertical component. The records have also shown what a large proportion the negative radiation bears to the amount of radiation falling to the earth during the day. The radiation is continually varying throughout the whole night.

These instruments have also been successfully employed to measure boiler radiation, more especially to compare the relative efficiency of various boiler laggings.

Calometric.—The Siemens water calorimeter is so well known that there is no necessity to describe it in detail. A ball of copper, iron, or platinum of known weight is exposed to the heat of a furnace, and is then transferred to a vessel containing a measured quantity of water at a known temperature. It can readily be seen that, knowing the rise in the temperature of the water, owing to the insertions of the hot body, and the specific heat of the metal ball employed, the temperature of the furnace can be deduced.

Fusion Thermometers.—Reference must be made to the excellent work of Seger in producing a series of cones melting at various temperatures by varying mixtures of quartz, sand, felspar, &c., and to the work of Mr. Henry Watkin in the same direction. I should also like to draw attention to an ingenious

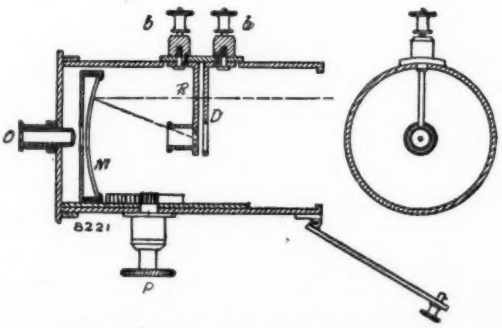


FIG. 24.—FÈRY RADIATION PYROMETER TELESCOPE.

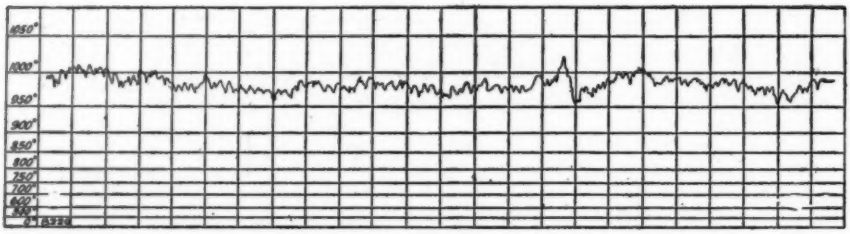


FIG. 25. TEMPERATURE RECORD FOR 24 HOURS OF A STEEL ANNEALING SURFACE ATTAINED WITH A FERY RADIATION PYROMETER AND THREAD RECORDER. MAXIMUM RANGE ABOUT 75 DEGREES.

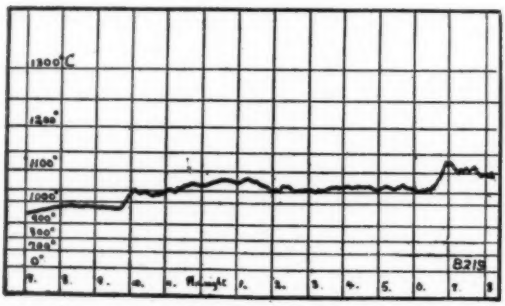


FIG. 26.—RECORD OF THE TEMPERATURE OF A POTTERY "BISCUIT" KILN ATTAINED WITH A FERY RADIATION PYROMETER AND THREAD RECORDER.

device invented by Messrs. E. H. Griffiths & W. C. D. Wetham. An iron rod is held rigidly in a steel tube by means of an alloy melting at any given temperature. The rod is free to rotate as soon as the alloy is melted, and can be made to ring an alarm either mechanically or electrically or to shut off gas, steam, &c. By a simple contrivance it can easily be reset for another experiment.

I feel that I have only touched on the fringe of thermometry and its many applications. The number of these applications must increase as the demand for scientific accuracy increases in all our large industries.

The Design of Engineering Workshops.—VI.

By H. MUNCASTER, A.M.I.Mech.E.

Roof Trusses.—These are now almost entirely made of rolled steel bars of suitable sections, such as angles, tees, flats, and sometimes of channel and H sections. Wooden principals, and composite trusses of wood and iron, are not usual among the best classes of engineers' workshop roofing. For slated roofs, however, wood purlins and "sarking" boards, to which the slates are nailed, are still very largely employed. The roof is generally of a comparatively flat pitch, the rise being about one-fourth to one-fifth of the span. This is quite satisfactory where the covering is of galvanised sheets of glass, but where slates are used the pitch should not be less than one-fourth or 26½ degs. on the slope. The writer's practice, except in very large spans, is to make the slope 30 degs. where slates are to be used as a covering.

There are two principal methods of trussing: the "king tie" or English, and the "queen tie" or French. *A*, *B*, and *C* (Fig. 37) show the first type, and *D*, *E*, *F*, the latter type. Where the roof is hipped the "king tie" is sometimes preferred as the hip rafters, and half principals are so arranged that the rods and struts meet in a common centre at the lower end of the "king tie." In the French type, however, the hips are trussed so that no centre tie is needed, and there is consequently no connection to the centre tie, thus avoiding the very complicated joint that occurs at the "king tie" in the English type.

A form of roof very common where wood is employed is shown in diagram at *G*. This form is quite unsuitable where steel is employed, and would not be sufficiently stable, except ties were fitted from *A* to *D* and from *B* to *C*, or else a stiff girder were used as a tie beam. Either of the forms shown at *B* or *E* would be preferable, and would allow of a much lighter construction for an equal strength.

In designing the trusses it is necessary to take into consideration the loads due to wind pressure, and, if the slopes are less than 30 degs., the weight of snow in addition to the dead weight of roofing.

The allowance for wind pressure should be about 45 lbs. per superficial foot coming in a horizontal direction, and the resultant of the forces of wind pressure and weight taken into account, with a factor of safety of 4 to 5, when calculating the size of the various members.

Up to 25 ft. span, the writer prefers the truss shown at *A* (Fig. 37) details of which are given in Fig. 38. The rafters are of 3 ins. by 3 ins. by $\frac{5}{16}$ in. tee, joined by ¼ in. plates. No smith's work

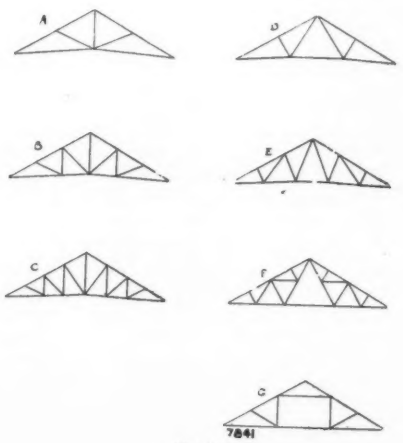


FIG. 37.

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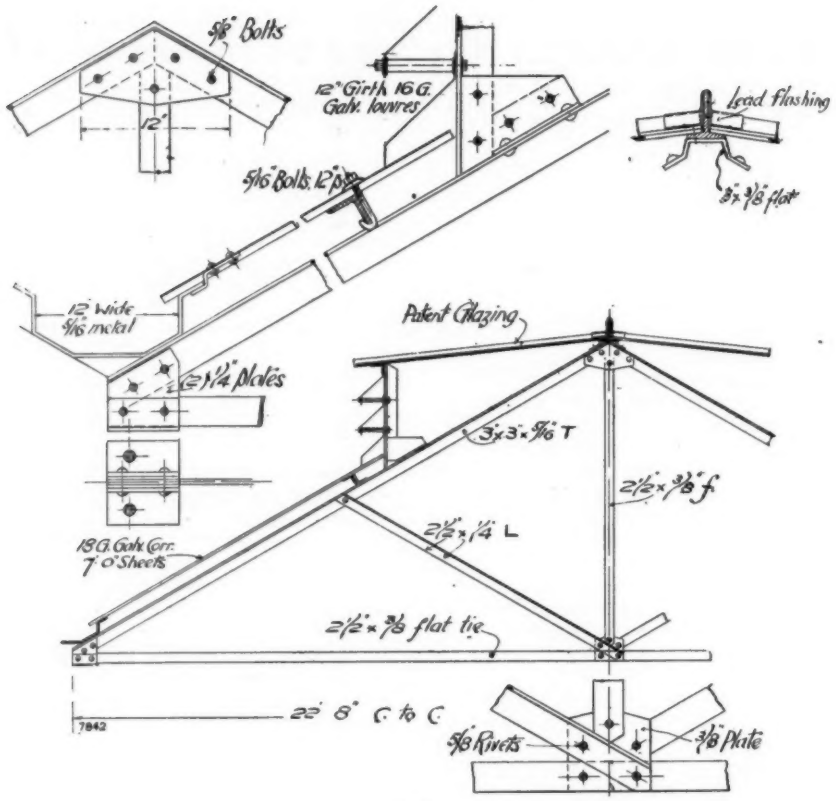


FIG. 38.

occurs in any part of this truss or connections; with the exception of the flat bar bent to carry ridge, the parts are cut to templet from the bars and plates, punched and riveted together.

The roof from which this example is taken, is fitted over a range of boilers, and is carried on light lattice girders extending from the front of the boilers to the engine house wall, each span covering two 8 ft. diameter boilers. Ample lighting and ventilation is provided by the raised louvre, which is covered by patent glazing. The louvre blades are of No. 16 gauge galvanised steel, 12 ins. wide, pressed to the form shown by hydraulic pressure.

The corrugated sheets are held at the top end by means of $\frac{5}{16}$ in. hook bolts engaging the web of the angle iron purlins. The bolts are about 12 ins. pitch. The lower ends of the sheets rest on a cast iron gutter, and are secured thereto by flat iron clips as shown.

Fig. 39 gives details of a 40 ft. span roof truss of the most simple construction, arranged for sheeting on one slope, the other slope for glass; the latter being the northern slope. The struts are of flat bars, bowed, set in pairs with distance pieces between. Enlarged details of the various joints are shown. This form of truss may be safely adopted for spans up to 50 ft. with the parts proportionately strong.

Fig. 40 shows an example of a roof principal of 55 ft. span of the "F" type (see Fig. 37). The principal rafters in this case are composed of two angles, back to back, with distance pieces between. The tie is also made of angles with a view of adding stiffness to the building by acting as struts when any heavy loads are being lifted on the jib cranes which are attached to the columns carrying the roof. Moreover, a flat bar of a sufficient strength to act as a tie would be of an extreme width and unsightly.

Sometimes round bars are used as ties with forged ends, in the case of all the members in tension, the idea being to save material. It is also often said that a round bar looks better and makes a neater finish. With regard to the saving of material, the writer is of opinion that this is not generally the case, because where a jaw is required, a lot of iron is worked up to get the necessary strength, as it is desirable to make the rods of extra size where there is a weld. Even then it is hardly safe to rely on the full strength of the rod. It is not practicable to do without a weld at each end of each rod, and the normal size of rod would require to be increased to cover the risk of imperfect welding. In the case of an angle or flat bar, the amount taken out by the rivet hole would have to be allowed for, which does not need to be of large size, on account of the ease with which a number of rivets can be used if required; the extra metal, therefore, would not be very much. The cost of the extra weight of material will be more than covered by the saving in wages gained by using flat bars.

With regard to the appearance in a workshop, this is not often a matter of concern. But, as a matter of taste, a flat or angle tie seems to harmonise with the other members better than a round bar,

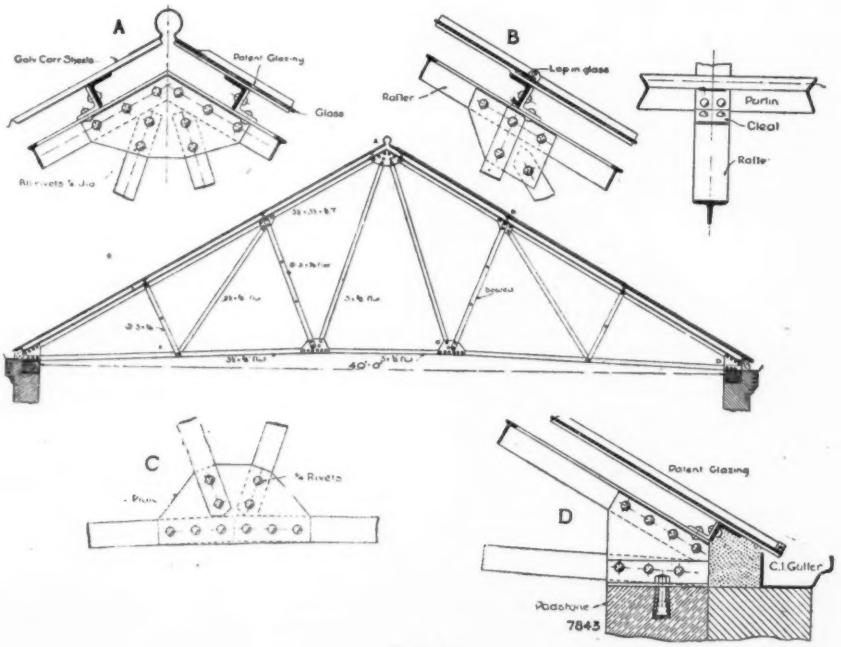


FIG. 39.

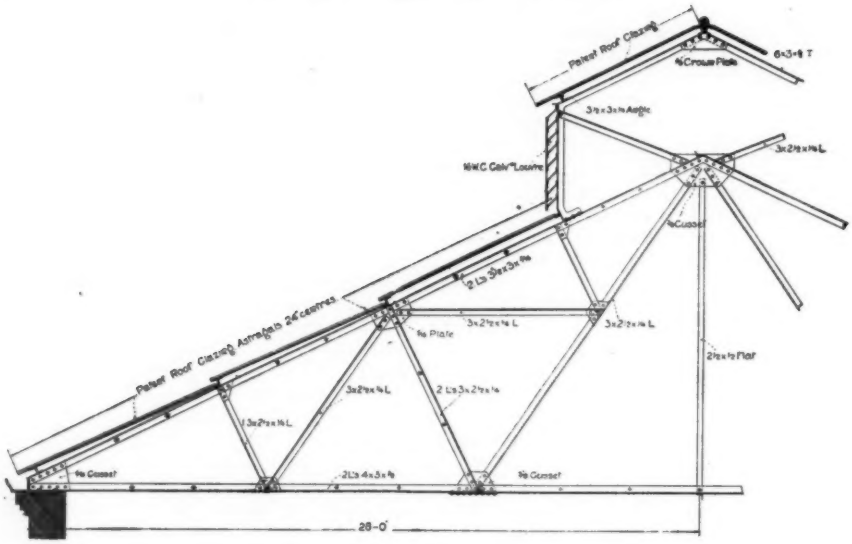


FIG. 40.

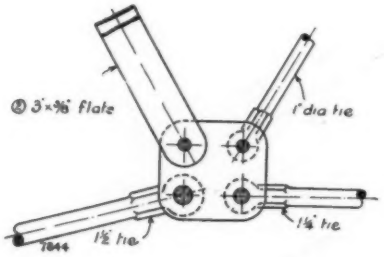


FIG. 41.

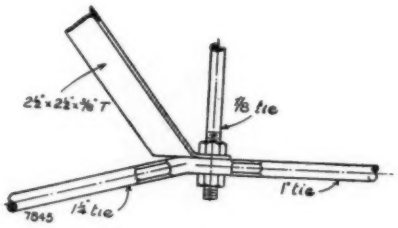


FIG 42.

and certainly admits of a neater and more effective joint where the members are connected together.

Another point is worth notice, viz. :— Designs are often submitted to structural engineers for tenders, having a great number of different sizes of similar section. Some time ago, for instance, a design for a roof principal was sent out for tenders from the borough engineer's office in a North of England town, having not less than eight different sizes of round bars, and a corresponding variety of tees, angles, plates, pins and rivets. In a case like this, the price would be probably much more than

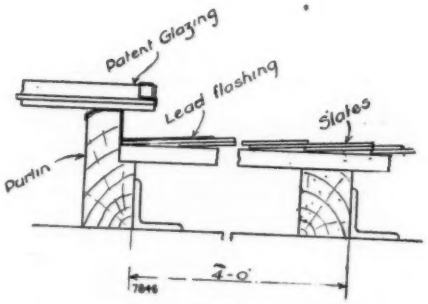


FIG. 43.

would cover the extra material used if the bars were made of the next marketable size, and the delay and extra worry

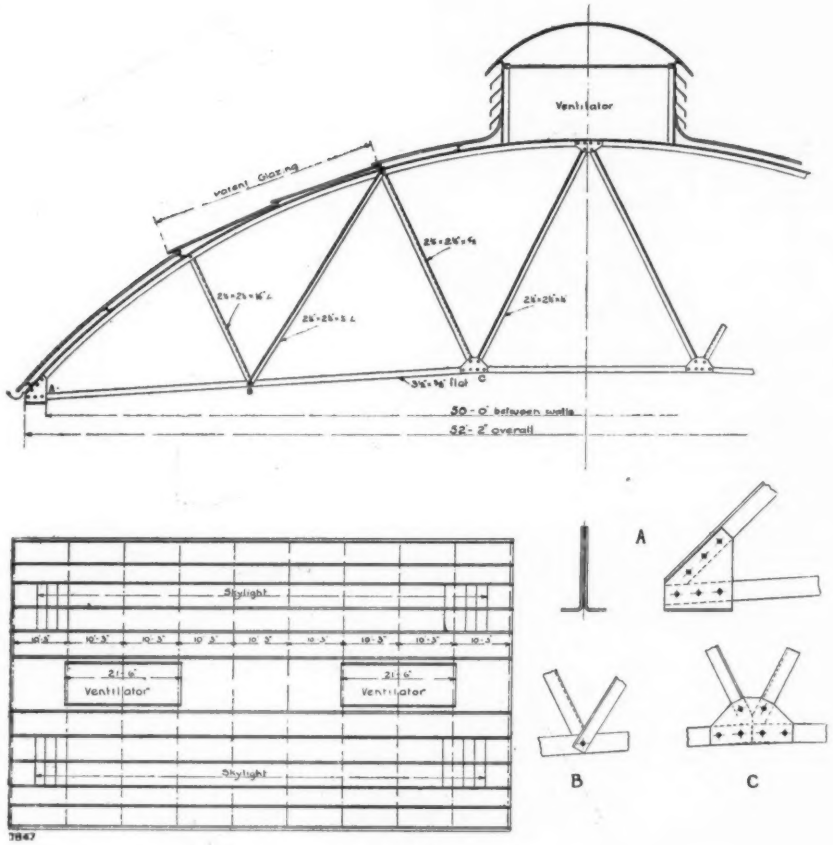


FIG. 44

in finding and sorting the odd sizes considerable. With regard to the joints where round bars are employed, Fig. 41 is given as a type of joint to be avoided. Unfortunately it is very commonly met with. The fault is that a considerable amount of oscillation is unavoidable on account of the varying amount of strain on the different members, especially during stormy weather, causing the pins to wear rapidly.

Another faulty form of joint is shown in Fig. 42, also very common. The strut presses against the screw thread, which rapidly disappears at that spot. The vertical tie is, on account of the screw thread, reduced to less than the strength of a bar of a diameter equal to to the diameter at the bottom of the thread, so that its effective strength would, in the case of, say, a $\frac{7}{8}$ in. diameter rod, be less than two-thirds of the strength of the bar, a defect that the adoption of round bars is intended to avoid.

The purlins in the foregoing examples are all of steel angles. For carrying corrugated sheeting, the writer's practice is to use 3 in. by 3 in. by $\frac{3}{8}$ in. steel angles for purlins where the

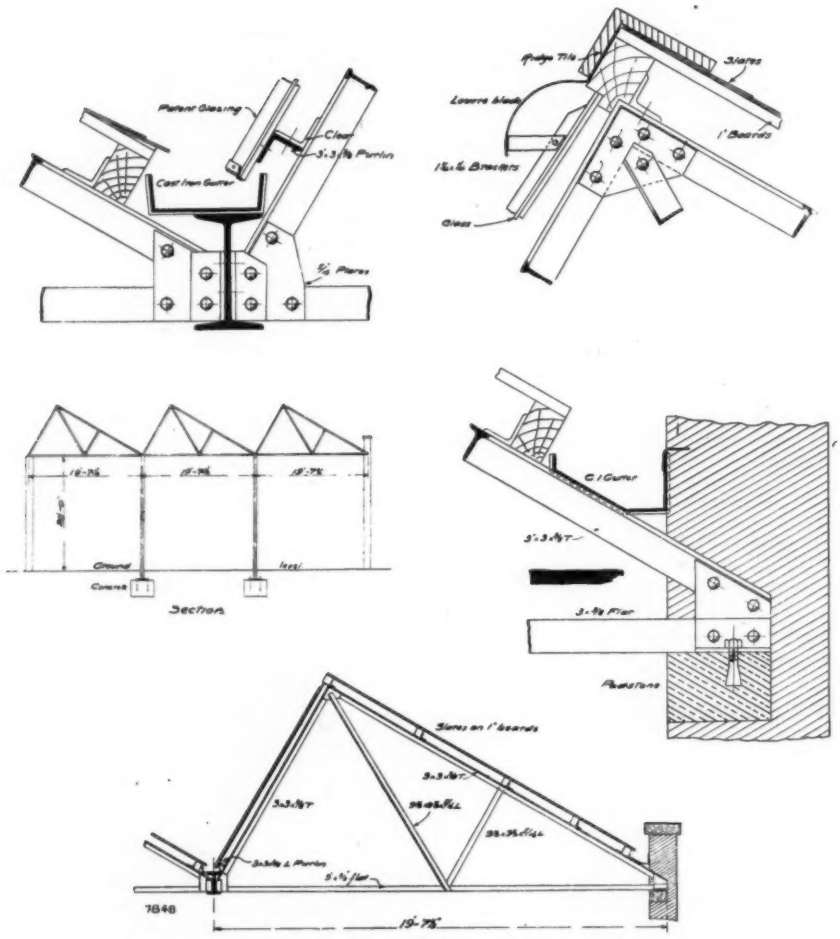


FIG. 45.

principals are about 12 ft apart, and reducing to $2\frac{1}{2}$ in. by $2\frac{1}{2}$ in. by $\frac{5}{16}$ in. where they are 10 ft. apart, the distance being about 6 ft. from purlin to purlin in each case.

Where the roof is to be boarded for the slating, wooden purlins may be used without any angles, say $4\frac{1}{2}$ in. by 3 in. for a 10 ft. pitch of principals, and about 4 ft. apart, centre to centre. This will carry 1 in. thick tongued and grooved sarking boards, which may be nailed vertically or diagonally.

Fig. 43 will explain the method of arranging, glazing and slating on the slope of a roof of 30 deg. pitch. The slates should be nailed to the sarking boards by copper nails. A lead apron, or flashing, is required over the purlin at *a*, extending down the slates a distance of at least 6 in. Slates are sometimes laid on light angle purlins of, say, $1\frac{1}{2}$ in.

by $1\frac{1}{2}$ in. by $\frac{1}{4}$ in., and attached thereto by copper slips of about $\frac{3}{8}$ in. wide by $\frac{1}{16}$ in. thick.

There are several good methods of patent glazing, such as Mellowes' "Eclipse," and others, where the glass is held by lead flaps on the lead cover of a steel or other bar.

In some makes of patent glazing, the glass is laid on a strand of asbestos or other fibre. This is, however, liable to perish and fall away in the form of dust, leaving the glass loose in the bar. Bars are made up to 11 ft. in length and strong enough to carry the glass, so as not to require any support in the middle.

Sometimes a plain T bar is used for the astragals and the glass bedded in putty. Great care should be taken in laying this to have the bar perfectly dry, otherwise the putty will not adhere properly, and will afterwards allow the rain to leak through. A wooden peg should be driven through the bar at each end to secure the glass and hold it until the putty dries.

A number of different sorts of roofing material have been introduced of late years, which have been more or less successful. Among the best known are "Uralite," "Wire Wove," "Ruberoid," &c.

A design for a circular rafter truss is given in Fig. 44. This is more suitable for corrugated sheeting which is bent to suit the curve, and is not generally adopted for roofs requiring to be slated.

There is slightly less covering required for the same area in proportion, compared with the flat slope roof, but the joints in the sheet near the crown are nearly horizontal, and apt to leak in wet weather, if not carefully made and maintained.

A form of roof at one time very popular is that known as the "Saw Tooth" or "North Light" roof, an example of which is given in Fig. 45, the idea being to get as much light as possible, without admitting direct sunshine.

The design of roof work is a speciality, and a great many things go to the making of a really good, though not necessarily expensive, roof. The text books are full of examples which should not be followed, and, without any other guide, many a junior is set to work out designs for new shop extensions. Any good firm will supply reliable designs if requested, and the experience of the experts of such firms as Sir W. Arrol & Co.; Messrs. Heenan and Froude; Messrs. Head, Wrightson; and many others, if called in, will often help to save expense, and to ensure the efficiency of the work.

RAILWAY ENGINEERING NOTES.

Arc Lamps for Railway Car Illumination.

The use of electric lamps for illuminating railway carriages has been on the increase for some years, and at present, owing to the luxury of trains in general, the electrical engineer is heeding the constant demands of the public and concentrates his efforts along the line of more efficient illumination.

An article in the *Electrical World* describes a system of arc lamps recently installed in a carriage on the Chicago and North-Western Railway, which has many features and characteristics that are receiving more than passing attention in railway circles.

The car, an interior view of which is herewith given, is of the Pullman standard 55-ft. type, and has an interior equipment consisting of three small enclosed arc lamps, rigidly fixed in position upon the ceiling as shown, the customary protective devices and controlling switch being placed in the saloon in the end of the car, well concealed from the public. The lamps are an adaptation of a regular type of lamp, and are fitted with a somewhat special type of an opal shade. The entire lamp is mounted and braced so as to prevent vibration with respect to the car. Experience has shownthat the vibration of the car itself has no effect upon the operation of the lamp, which is equally as good at standstill, low, or high speed.

PULLMAN CAR ILLUMINATED BY ARC LAMPS.

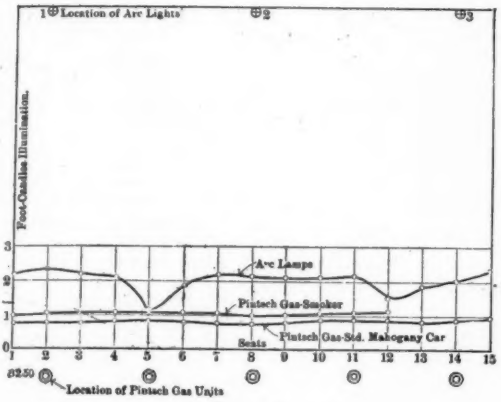
The lamps are operated in parallel from a straight storage battery system, the rated capacity of which is 120 ampere-hours, placed in a compartment under the car. The compartment is 15 ins. high, 20 ins. deep, and 65 ins. long, and contains 50 cells arranged in 5 trays of 10 cells each. The weight of battery equipment complete is 1,350 lbs.

The life of the carbons in the small enclosed arcs used on the car will approximate 40 hours for positive and 40 hours for negative, or one new carbon every 40 hours. The cost of maintenance can be readily seen to be less than for incandescents where carbons are 64*s.* per thousand, or about 12*s.* to 16*s.* per lamp per year, and incandescents numbering 20 to 40 per car at 10*d.* for each 500 hours.

The arc lamps approximate 200 candle-power each with globes complete, and have a consumption of 300 watts, giving about 1½ watts per candle. These three lamps replaced the former installation of five "Pintsch" gas units of approximately 36 candle-power each, or a total of 180 candle-power in the car.

The tests of the distribution of illumination in this car show well the features of the system, and from a study of the curves one is enabled to judge the results that could be secured by making slight changes in the installation.

The results herewith given were secured while the car lay in the Waukegan yards with all conditions exactly as when the car is on the road. A duplicate test was carried on in a car of the same type fitted with five "Pintsch" gas units, which were operating exactly in the same manner as when on the



AVERAGE DISTRIBUTION OF ILLUMINATION.

road and with glassware clean. The test in the car with the Pintsch gas system, however, was carried on solely for results that would be found in practice, no manometer or meter being placed in the system, for the object was merely to study the difference between the commercial results obtained by the two systems for the same car.

One arc is located in the centre of the car at seat No. 8, and the two end arcs are 18 ft. from the centre and 9 ft. 6 ins. from either end at seats No. 2 and No. 14 respectively. Instruments were in the line throughout the test, which gave an average e.m.f. over each lamp terminal of 96 volts and a total line current varying from 8·3 to 8·5 amperes, or about 1·35 watts per candle.

Turning our attention now to the curve representing the performance of the Pintsch gas system under commercial conditions in a standard type mahogany car, we see that the distribution is remarkable for uniformity. The specific readings were easily obtained and were very uniform, so that only average values are given as shown by the curve; but, as with the arcs, these values are the average of six readings.

The general average illumination for the Pintsch gas system with units approximating 180 candle-power in a car was found to be about ·75 foot-candle, while that of the arc is about 2½ times greater for approximately 600 candle-power of units.

4-4-0 Type Express Passenger Engine, Midland Railway.

There has recently been put into trial service on the Midland Railway a new type of express locomotive, designed by Mr. R. M. Deeley, which has several new features. It is a two-cylinder non-compound engine and is, we understand, being tested on services in which the three-cylinder compound engines are at present employed.

It is fitted with a similar boiler to that employed on the compounds, viz., Belpaire type, with front end extension, providing steam at 220 lbs. per sq. in. and having a total heating surface of 1557·4 sq. ft. The cylinders, which are 19 in. by 26 in. stroke, form with the steam chest and saddle one casting. Steam distribution is by piston valves working above the cylinders. The novel feature, however, is the valve gear, in which neither eccentrics nor return cranks are employed. By the courtesy of Mr. Deeley, detailed drawings of this gear will be given in our next issue. There are other departures in connection with the driving and trailing axles which are fitted with axle boxes

NEW TYPE OF TWO-CYLINDER SIMPLE ENGINE, WITH SPECIAL VALVE GEAR: MIDLAND RAILWAY.

of a new design, each having two cylindrical brasses free to adjust themselves to the bearings. For the first time in Midland Railway locomotive practice the swing link type J bogie is utilised.

The coupled wheels diameter is 6 ft. 6½ ins. with a rigid wheel base of 9 ft. 6 ins.; weight of engine and tender, in working order, 104 tons 9 cwt.; and the tractive power, ·0534 ton per lb. of steam pressure.

The Derelict Potteries Railway.

The final decision of the Light Railway Commission as to the proposal for resuscitating the remarkable Shrewsbury, Potteries, and North Wales Railway, which has now been in a derelict condition since 1880, has yet to be announced, but judging by the attitude of the Commissioners at the proceedings there is a strong probability of the finding being in favour of the revivification of the line.

The inception of the railway dates back to the year 1862, when a scheme was formulated for the construction of a mineral line between Llanymynech and Westbury. This route was subsequently modified in favour of a continuation to Red Hill, with the object of gaining access to Shrewsbury over the Great Western and London and North Western joint line.

These running powers were, however, refused, and the company subsequently constructed a line of its own to that town. The main line, 18 miles in length, from Shrewsbury to Llanymynech was opened in 1866, and two or three years later, following on an amalgamation effected with the Shrewsbury and Potteries Company, branch lines were opened from Kinnerley to Criggion, six miles; from Llanymynech to Llanyblodwel, 2½ miles; and from Shrewsbury to Potteries Junction on the Shrewsbury and Wellington joint line.

A further project of the Amalgamated Companies, who now styled themselves the "Potteries, Shrewsbury and North Wales Junction Railway," was the continuation of the line *viâ* Bala, Festiniog, to Portmadoc on the coast, but this was never carried out.

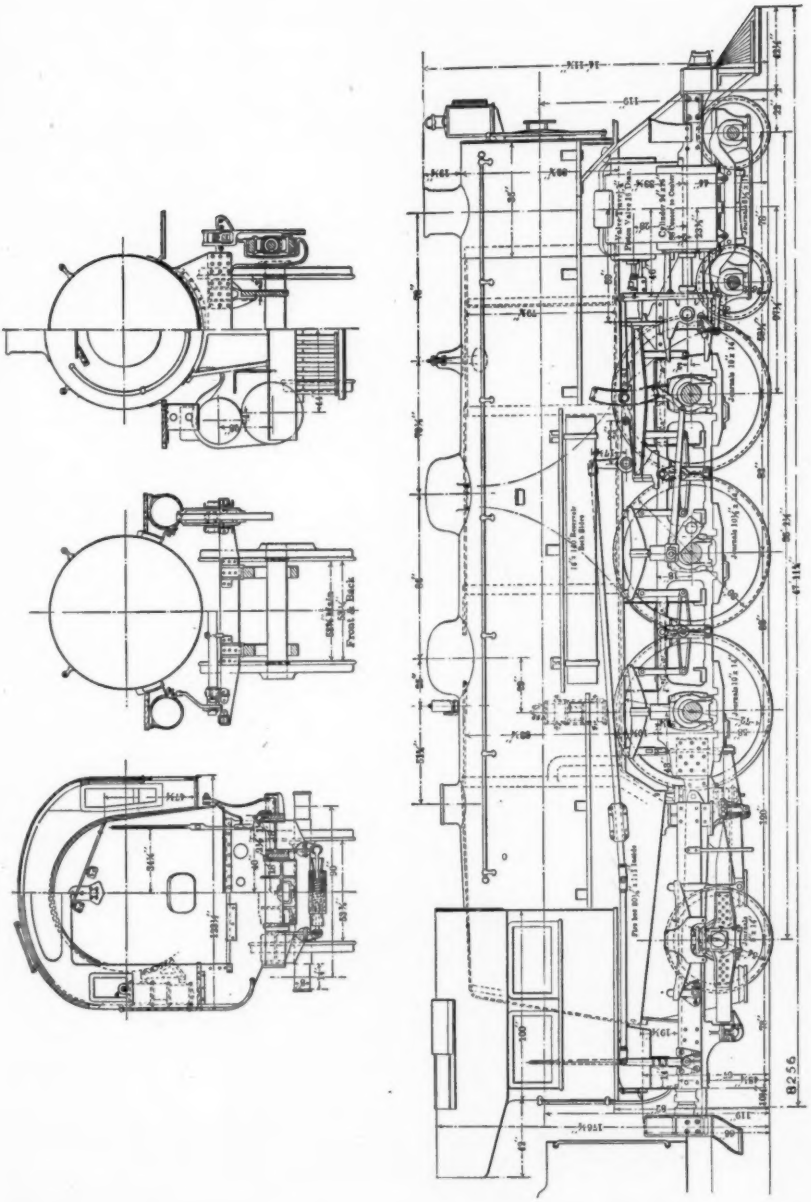
After a succession of misfortunes a Government Commissioner ordered the line to be closed in June, 1880, since which date it has never been worked, although several attempts have since been made to effect a re-opening without success.

Death of Mr. W. G. Bagnall, of Stafford.

We regret to record the death of Mr. William G. Bagnall, of Castle Hill House, Stafford, founder and managing director of the firm of W. G. Bagnall (Limited), Castle Engine Works, Stafford, which took place at his residence on the 2nd ult. The deceased gentleman, who was 53 years of age, was not only the pioneer of one of the leading locomotive engineering firms in the Midlands, but, until ill-health necessitated his retirement, devoted himself with energy and ability to public work, he having been a prominent member of the County Council and the Stafford Town Council. The deceased gentleman was born at Cliff Hall, Tamworth, was educated privately, and commenced his business career in a bank, where he remained for two years, and then entered the works of Messrs. John Bagnall & Sons, of West Bromwich, of which he eventually became a director. In 1876 he removed to Stafford and took what was then a small millwright's business carried on under the style of Massey and Hill. Mr. Bagnall shortly afterwards commenced the manufacture of a small class of locomotive which ultimately became the chief product of the Castle Engineering Works. With narrow-gauge light railways Mr. Bagnall was specially successful, and the light railway of Spezia Harbour, which was particularly difficult in its gradients and curves, was designed and carried out by him. Mr. Bagnall also brought out a special design of locomotive adapted to the difficulties of the light or narrow-guage railway curves and heavy locomotives of the American style, with cowcatcher, and designed for the maximum haulage on light railways. As a builder of these locomotives, together with the requisite rolling stock, Mr. Bagnall achieved a high reputation. From 1882 to 1895 Mr. Bagnall continuously served on the Stafford Town Council, from 1892 filling a seat on the aldermanic bench. The deceased was one of the original members of the County Council. As a Conservative, he contested the West Ward of Stafford at the first election in 1889, and received 805 votes, defeating Mr. J. C. Mycock by 448. Mr. Bagnall has left a daughter and two sons, one of whom takes an active interest in the Castle Engine Works.

The Largest Passenger Engine ever built.

The problem of keeping pace with the rapidly increasing demands of express



THE LARGEST LOCOMOTIVE EVER BUILT. ELEVATIONS AND SECTIONS OF 135-TON PASSENGER ENGINE: PENNSYLVANIA RAILROAD.

passenger service is not confined to British railways, but is confronting American locomotive builders to an equal if not increased degree.

Especially has this been the case on the Pennsylvania lines, which for some time past have been employing as their standard locomotives powerful machines of the Atlantic type, the largest of which have cylinders 22 in. by 26 in., 6 ft. 8 in. driving wheels, 5 ft. 7 in. Belpaire boilers generating steam at a pressure of 205 lbs. per sq. in.

These have hitherto been handling successfully the standard eight car trains over the division of line involving steep gradients, but their limits of power have been surpassed now that it is found necessary to employ trains of ten, twelve or more cars. The company, having set themselves against the practice of double heading, decided to adopt a powerful locomotive of the Pacific type, with the result that the American Locomotive Company have recently delivered for trial service an engine which in point of size and weight exceeds any hitherto constructed. It weighs 134·6 tons, and with tender loaded with 11 tons of coal and 7 tons of water, totals 204·6 tons. The cylinders are 24 in. diameter by 26 in. stroke, and the piston valves, which are operated by the "Walschaert" gear, are themselves 16 in. diameter. The valve gear, which has been carefully designed with a view to bringing its working parts into one plane, is provided with a special supporting frame outside of the link. The frame will be observed in the accompanying illustration of the engine. Only in tractive effort does it fail to score a record, that being held by the large 2-6-2 type balanced compounds of the Santa Fé railroad, because of the smaller driving wheels and higher steam pressure employed on the latter. The following figures will permit of a comparison of the two types being made:—

	P. R. R.	A. T. & S. F.
Road		
Type	2-6-2	2-6-2
Simple or comp.....	Simp.	Comp.
Total weight, lbs.	269,200	248,200
Weight on drivers, lbs. ...	173,550	174,700
Tractive effort, lbs.	32,700	37,800
Size of cylinders	24″ × 26″	17½″ & 29″ × 28″
Diam. drivers	80″	69″
Steam pressure, lbs.....	205	225
Total heat surface, sq. ft...	4,427	4,020
Length of tubes	21′	18′ $10\frac{5}{8}$″
Grate area, sq. ft.	61·8	53·8
Total H. S. ÷ grate area...	72	74
Total H. S. ÷ vol. cyl.....	326	334
Total weight ÷ total H. S.	61	62

The general details of the design will be gathered from the accompanying outline drawing, for which we are indebted to the *American Engineer and Railway Journal*. The following are the principal dimensions and weights:—

Cylinders, 24 in. by 26 in.
Piston valve, 16 in. diam. by 7 in. stroke.
Boiler—
- Diameter, first ring, 29¾ in.
- Pressure, 205 lbs. per sq. in.
- Firebox, 111 in. long by 80½ in. wide.
- Tubes, 343.
- Tubes, 21 ft. by 2¼ in.
- Heating surface—
  - Tubes, 4,222 sq. ft.
  - Firebox, 205 sq. ft.
  - Total, 4,427 sq. ft.
- Grate area, 61·8 sq. ft.

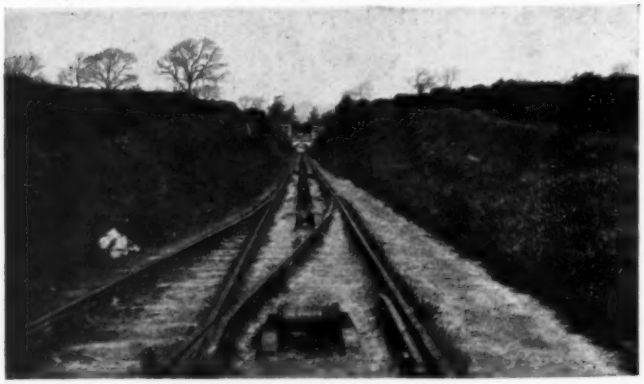
Driving wheels, diameter, 6 ft. 8 in.
Bogie wheels, diameter, 36 in.
Wheel base—
- Total engine, 35 ft. 2½ in.
- Total engine and tender, 67 ft. 3 in.
- Driving, 13 ft. 10 in.

Weights—
- Front truck, 46,175 lbs.
- Front drivers, 59,000 lbs.
- Main drivers, 57,675 lbs.
- Back drivers, 56,875 lbs.
- Trailers, 49,475 lbs.
- Total locomotive, 269,200 lbs.
- Tender, 140,000 lbs.

Tractive power, 31,000 lbs.
Tender—
- Water capacity, 7,000 gals.
- Coal capacity, 22,000 lbs.

RATIOS.

Weight on drivers ÷ T. E. 5·6, or 17·86 %.



VIEW LOOKING DOWN SWANNINGTON INCLINE (OPENED 1833 AND STILL IN USE 1907.)

Total weight ÷ T. E., 8·7, or 11·5 %.
T. E. × Diam. of drivers ÷ H. S., 560 (B. D.)
Tube H. S.
———————— ÷ F. B. H. S., 1,126 sq. ft.
√ tube length
Total H. S. ÷ G. A., 71·6 sq. ft.
F. B. H. S. ÷ total H. S., 4·6 %.
Weight on drivers ÷ total H. S., 39·2 sq. ft.
Total weight ÷ total H. S., 60·8 sq. ft.
Vol. both cylinders, 13·61 cu. ft.
Total H. S. ÷ cylinder vol., 325·3 sq. ft.
G. A. ÷ cylinder vol., 4·5 sq. ft.

The Leicester and Swannington Railway.*

The Leicester and Swannington Railway is one of the oldest and most interesting lines in the kingdom, having been opened for traffic on the 17th of July, 1832, or seventy-five years ago. The names of William Stenson, John Ellis, George Stephenson (the father of railways), Robert Stephenson, and Thomas Paget, will ever be remembered in connection with the undertaking.

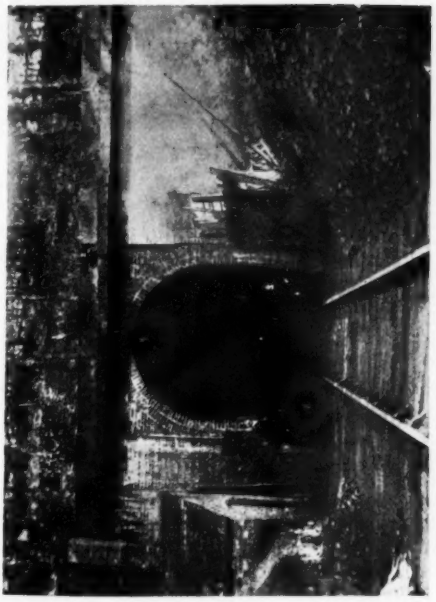
For many years coal was brought to Leicester by canal, but in winter time the canal was frozen over. Mr. Robinson had the greatest difficulty in obtaining coal even to supply the gas works, and the price was so high that poor people had to live without fires.

The chief object of the railway was to provide a constant and cheap supply of coal for Leicester, and it is due to the cheap coal that new industries were started, and, in fact, the line made the town and caused it to become one of the greatest trade centres in the country. However, this railway must not be viewed simply as a local line to convey coal and passengers to Leicester, for it has a far more important and more interesting history, namely, that it is the oldest portion of that vast railway system which extends practically over the greater part of England, and portions of Wales and Ireland. It is the foundation stone upon which the Midland Railway system has been built.

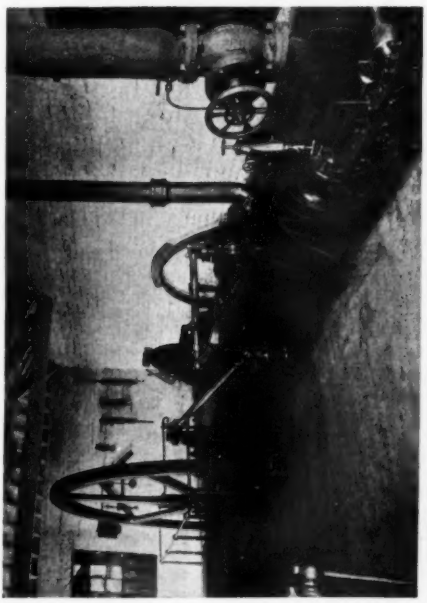
The Leicester and Swannington Company obtained its Act in 1830, and work was commenced towards the close of that year.

Leaving the West Bridge station at Leicester, the line passes through

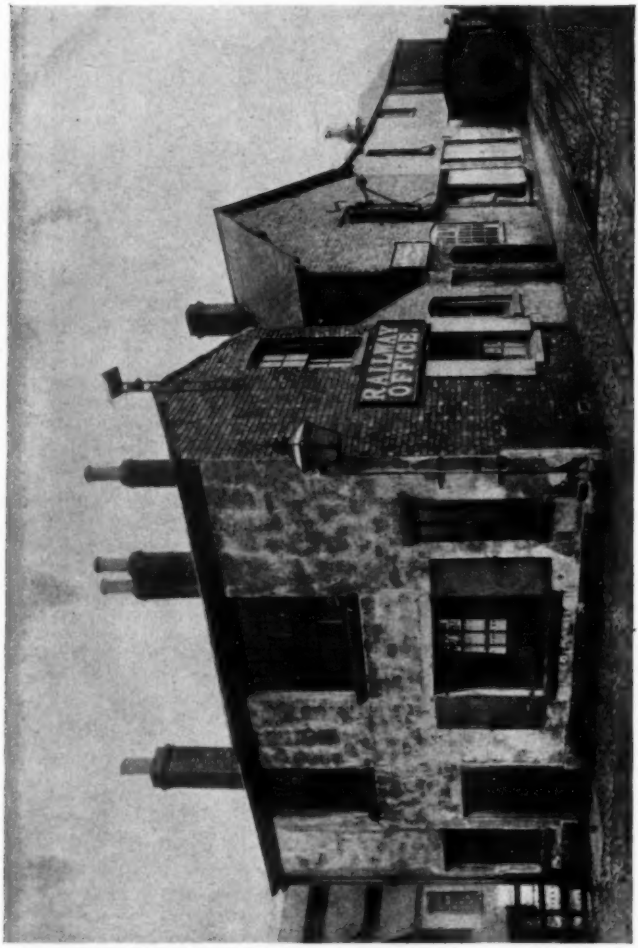
* Paper read by Mr. Clement E. Stretton, at a meeting of the Railway Club at Leicester, on the occasion of the 75th anniversary of the opening of the railway.



GLENFIELD TUNNEL (OPENED JULY 17TH, 1832).



WINDING ENGINE, SWANNINGTON INCLINE, 1833, AND STILL IN USE 1907.



WEST BRIDGE STATION, LEICESTER (OPENED JULY 17TH, 1832, CLOSED MARCH 13TH, 1893).

the Glenfield tunnel, Glenfield, Ratby, Desford, Merrylees, Bagworth, Bardon Hill, and Coalville to the termination at Swannington, a distance of 16¼ miles.

The chief work was the Glenfield tunnel, which is 1,796 yards in length, perfectly straight and level; it has a single line of rails only, and is 14 ft. high, and 12 ft. wide at the springing of the arch; it is built of 18-in. brickwork. Loose running sand caused great trouble in the construction, a wooden tunnel having to be made to hold up the sand until the brickwork could be put in. The work was carried out from both ends and in each direction from four large shafts.

The extra cost of construction, due to the sand, was so great that the contractors were ruined, and the company had to take over the work and complete it.

On the opening day, July 17th, 1832, a special train ran from Leicester West Bridge to Bagworth, at 10 a.m., and conveyed the directors and citizens of Leicester. Unfortunately the chimney of the engine *Comet* caught the top of the tunnel, with the result that the chimney was knocked down, and the passengers travelled to the Glenfield end through thick smoke and dirt, and the train was stopped at the Glenfield brook to enable them to wash their faces and hands.

At Bagworth there was a severe incline of 1 in 29, worked by a rope, the full wagons of coal by gravity pulling the empty ones up; upon this incline locomotive engines did not work. In 1848 a new (the present) incline was constructed at the side in order to avoid this inconvenience.

The Swannington incline of 1 in 17 was in 1833, and is to-day, worked by a fixed winding engine and rope; the original engine is still in use, but there have been several new ropes supplied.

To enable the railway to cross over the canal into the Soar Lane Coal Wharf at

Leicester, Mr. Robert Stephenson designed a lifting or draw bridge, balanced by counter-weights. It was brought into use in 1834, and is still at work, although recently extensively repaired.

The cost of the railway complete, to the year 1846, was £140,000, and at that date the Midland Railway Co. took over the undertaking, paying the Swannington shareholders 8 per cent. guaranteed dividend in perpetuity.

The coat of arms of the Swannington Co. was a fearful and wonderful creature, somewhat similar to a winged serpent, the wyvern. At the time of the Saxon heptarchy, Leicester was the capital of Mercia, and the wyvern was the crest of the Mercian kings; hence it follows that as the Swannington line is the oldest portion of the Midland system, the wyvern is perched on the top of the Midland Railway Co.'s coat of arms, and is painted on the engines and first-class passenger carriages. However, at the present time the crest is being removed, and the more useful figures 1 and 3 are being painted on the carriage doors.

With reference to the passenger train service, it is interesting to observe that in 1832 three trains a day conveyed passengers from the West Bridge station; they left at 8 a.m., 1 p.m., and 4.30 p.m. To-day there are still three passenger trains, but they start from West Bridge at 9 a.m., 1 p.m., and 5.30 p.m.

GLENFIELD STATION (OPENED 1832).

Accumulator Railway Cars in Germany.

The Prussian State Railways put into service last February a number of independent unit accumulator motor-coaches for short-distance local traffic on the lines in the neighbourhood of Mainz. These coaches, which are described in a recent issue of *Electrical Engineering*, run at a maximum speed of 28 miles per hour, and can travel about 37 miles without re-charging. For this purpose a number of ordinary three-axle coaches, formerly used in the Berlin suburban service, were rebuilt in the manner shown in the accompanying figure at the railway works at Tempelhof. The batteries were supplied by the Akkumulatoren Fabrik, and the motors and control gear by the Siemens-Schuckert Co. The coaches are divided into six compartments, with ten seats each and without corridors. The driver's seat is in an elevated cabin at either end, resembling the brakesman's cabin familiar in old-fashioned Continental rolling-stock, but larger and more easily accessible. The batteries are charged at the station at Mainz, and consist of 180 cells of a capacity of 200 ampere-hours. The cells are placed in lockers under the seats of the compartments, provided with ventilating cowls in the side panels of the coach. There are 15 cells under each set arranged in two lockers, and easily removable from above, as the seats are hinged. The drivers' cabins are provided with a controller, measuring instruments, main circuit-breaker, the necessary switches for the carriage lighting, and signal-lamp circuits, the apparatus for working the hand brake, and sanding arrangements. The fuses are all placed together behind the driver's seat, and the resistances are situated on the roof. The two motors are rated at 25 h.p. each, and series-parallel control is adopted in the usual way. They drive the front and rear axles respectively by single reduction gearing. The total weight of the vehicle is 38 tons, including batteries and all equipment, of which 14 tons is taken by each of the end axles, and 10 tons by the centre axle. The carriages are heated by a hot air system, with small stoves under the frame. Each compartment is lighted by a pair of

incandescent lamps. The signal lanterns each contain two lamps wired on different circuits. Two loud-toned electric gongs are provided for signalling purposes, and these can be actuated from each compartment as emergency signals. The car can, of course, be driven from either end, and communication between the two end cabins is provided by electric bells. In case of need, the conductor in the rear cabin can at all times stop the car independently of the driver.

Results of Use of Different Valve Gears on Locomotives.*

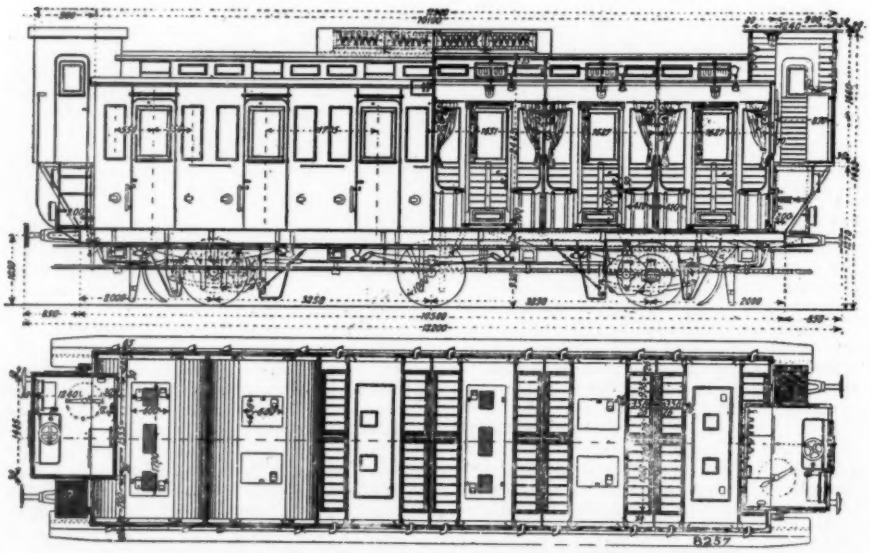
The Stephenson link motion has held its own almost without consideration being given to other types, until within very recent years. The types and weights of engines employed lent themselves to convenient use of this type of link motion, which has many desirable and valuable features to commend it.

The time came, however, when it became expedient to make changes for some of the following reasons: Some types of engines have so many wheels or they are so closely grouped that it is a difficult matter for enginemen to get under them except when over a pit. This contributes to neglect, lack of prompt adjustments for wear, lack of proper inspection and a more rapid deterioration. With the increase in size and weight, the dimensions of eccentrics required for large axles are excessive, and their peripheral speed is so great as to make maintenance and lubrication of the eccentrics and straps expensive and troublesome.

By the abolition of eccentrics and straps, a long list of engine failures is eliminated; expense for maintenance and lubrication reduced; room gained for better cross-bracing and strengthening of frames and adding to convenience on account of the men not being required to go under the engines to the same extent. On heavy engines, the weight of all moving parts of a link motion, from the eccentric straps through to the valves, is so great as to contribute to accident and rapid wear, so that an equally efficient valve motion with lighter parts and greater accessibility is in demand for heavy power.

For many reasons, we cannot lower the standard of efficiency as set by the Stephenson link motion. Economy in the use of coal and water are more necessary than a reduction in weight and wear of valve

* Extract from a Report of Committee of American Railway Master Mechanics' Association.



ACCUMULATOR CAR IN USE ON THE PRUSSIAN STATE RAILWAYS.

motion parts. No railway manager will sanction the use of a device, no matter how beautifully simple it may be, if his costs as measured in coal are increased thereby. Fortunately, we are able to obtain a valve motion having the desirable features of lighter parts and accessibility without a loss of efficiency in the Walschaert motion, which has come into extensive use the last few years.

The following tables of weights are given for a 22-inch consolidation engine, said to be identical in everything except the valve motion, built by the Baldwin Locomotive Works :—

	Complete Moving and Structural Parts.		Moving Parts Only.	
	Stephenson.	Walschaert.	Stephenson.	Walschaert.
Crossheads	676	746	676	746
Guide bearer	814	1,116	—	—
Guides	1,712	1,712	—	—
Eccentrics	600	—	600	—
Crank arms	—	250	—	250
Eccentric straps	1,100	—	1,100	—
Main crank pins	520	516	520	516
Links	238	418	238	413
Reverse shaft	325	655	325	655
Rockers and boxes	618	730	618	730
Rocker rods and hangers	169	—	169	—
Link bearing	—	234	—	—
Eccentric rods	184	264	184	264
Valve rods	220	546	220	546
Valve yokes	154	140	154	140
Valve rod guide	24	28	—	—
Complete set	7,354	8,321	4,804	4,265

It is a fact that similar valve motion parts on engines abroad are very much lighter than we dare use in our own practice. It seems fair to conclude, therefore, that we may yet look for improvement in this respect.

The matter of lead has received much attention, particularly with link motion, but, as a matter of fact, the measured full gear lead is only used possibly for a few turns of the wheels in starting the engine, and when running notches are in use the lead is entirely different, the amount being dependent upon various conditions. As the running notch leads for best results are within narrow limits, it is apparent that the full gear leads vary within a wide range. The amount of full gear lead is therefore of little importance in the operation of the engine if the running notch lead is right. If these premises are correct, then there can be no argument as against the constant lead characteristics of the "Walschaert" motion, provided the lead is the proper amount for the running notches. The valve motion diagrams show that all the other events as derived by a link motion can be duplicated by the "Walschaert" motion so that, except in so far as the lead is concerned, equivalent operation can be obtained; hence, equivalent economies.

The practical operation of "Walschaert" motion is best shown by the testimony of roads using it in considerable numbers, and at a recent meeting of motive power officers and locomotive builders, held to discuss the results of the use of "Walschaert" motion engines, the roads represented having about 1,000 such engines, it was the unanimous opinion that "Walschaert" motion was equally well adapted to fast and slow passenger and freight service; that equivalent economies in fuel and water were obtained; that no reductions of tonnage ratings were necessary; that expense of maintenance and repairs were reduced; that inspection and repairs were facilitated; that construction advantages in the way of frame-cross bracing, etc., were increased; that valve adjustments made are maintained and engines kept square much longer on account of the motion being more direct, rigid and positive for the passage of the valve-driving stresses; and that convenience of the enginemen, inspectors and shop men is promoted by the accessibility of the motion.

ELECTRICAL NOTES.

By ANDREW STEWART, A.M.I.E.E.

A New Type of Variable Speed Motor.

In an article contributed to the *Electrician*, Dr. L. Torda discusses at some length a new type of variable speed motor, or conversely a variable voltage generator. As is well known, variations in the speed of an electric motor are possible by varying the amount of current passing through the field winding. This variation being obtained by introducing a resistance in series with the shunt field, or by diverting some of the current in the series field through a bye pass in the shape of a resistance. The shunt machine is generally employed, and the disadvantages are that for wide speed ranges without loss of power, as is possible with shunt machines, a motor with very considerable margin is necessary; in other words, a frame larger than is required

FIG. 2.—VARIABLE SPEED MOTOR WITH ADJUSTABLE COVER REMOVED.

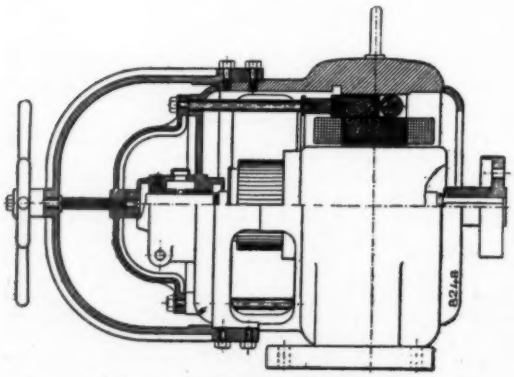


FIG. 1.—PART SECTION VARIABLE SPEED MOTOR.

by purely mechanical considerations must be used, as with the weak field at high speeds the commutation of the motor becomes unsatisfactory. The use of intermediate, or commutating poles has increased the possibilities of the shunt machine in this direction, by rendering the commutation of the motor independent of the main field magnetism, but this adds to the cost of the machine and the net gain is small.

There has been in use in the United States of America a type of variable speed motor

which utilises the principles expounded by Dr. Torda in the *Electrician*, but it is less simple, inasmuch as a considerable portion of the field magnet iron is withdrawn radially, *i.e.* through the yoke of the machine, the cores being connected together, and to a single operating wheel, by means of bevel gear.

The new machine, made, it appears, by the Morris-Hawkins Company, withdraws part of the magnet core in an axial direction. This will be clear from Fig. 1, which shows the machine partly in section, with the hand wheel and screw for withdrawing the core mounted outside the end bracket at the commutator end of the machine. As the hand wheel is turned the magnet core is withdrawn, and the field magnetism reduced, resulting in a corresponding increase in the speed of the motor.

Fig. 2 shows the magnet field with the armature and end brackets removed, showing the air gaps in the poles when the portions of the magnet core that are movable, have been withdrawn. Fig. 3 shows the machine as it appears when complete with the adjusting portions of the magnet circuit right out giving maximum speed. The speed curves of these machines appear very satisfactory, though it is not clear that, with such a weak magnetic induction at the air gap, the machine will be entirely satisfactory from the point of commutation, at the maximum speed. In any case the difficulties which arise on this score may be overcome, and the machine gives promise of being a very useful type for machine tool work, where there is a rapidly growing demand for a really robust type of variable speed motor.

Some Recent Developments in Single-Phase Traction.

An electric railway system with nearly 500 miles of track, and still extending, is of special interest for two reasons: first, it is a development of what we should call an ordinary electric tramway, though now running

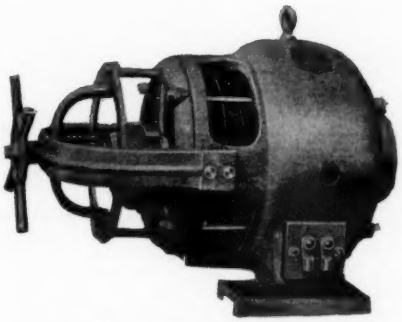


FIG. 3.—VARIABLE SPEED MOTOR, COMPLETE MACHINE.

to a large extent on a private right of way; second, it started with direct current; subsequently tried single-phase alternating current, and is now changing a considerable portion of the direct current equipment to single-phase alternating current. We have some years ago noted the development of the Illinois Traction Company's (U.S.A.) system, but the features now described are the developments of the last eighteen months. The bulk of the mileage is operated by direct current, but about sixty-eight miles are in operation with alternating current, and a further twenty-seven miles are under construction. Thirty miles of the alternating current system now in operation have been converted from direct to alternating current, though in all cases the alternating current cars and locomotives will run equally well on either system. The arrangements for so doing embody a few features of special interest which will be described later.

Interest centres on the alternating side, as it represents the most recent examples of such work, part having only been completed at the beginning of June.

The most recent power house, that at East Peoria, contains two "Curtis" steam turbines each of 2,700 h.p. coupled to three-phase generators of 2,000 kilowatts. The sets run at 750 revolutions per minute, and as the generators have four poles the periodicity

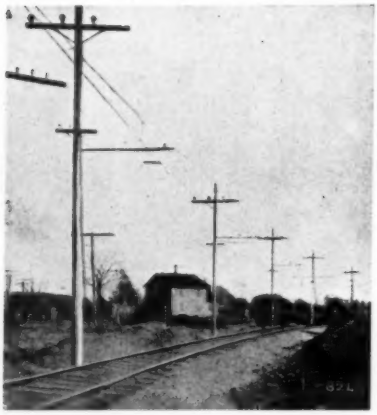


FIG. 4.—OVERHEAD WORK. ILLINOIS TRACTION CO.

is twenty-five cycles per second. Steam is supplied by "Stirling" boilers working at 190 lbs. per square inch.

The generators generate current at 2,300 volts, which is raised to 33,000 volts for transmission; it is reduced to 3,300 volts, which is the trolley wire pressure at sub-stations. The 33,000 volt transmission line is carried on cedar poles 40 ft. long, 12–14 in. thick at the bottom, 7 in. at the top.

The sub-stations comprise a waiting room, a goods and parcels room, and the sub-station proper, consisting, of course, of static transformers controlled by the usual switch gear. All is under one roof, and the entire station is more or less under control of the station master.

The overhead line is shown (Fig. 4), from which it will be seen that catenary construction has been adopted. An iron bracket 9½ ft. long is carried from the pole, and from this the steel messenger cable is suspended. It consists of a $\frac{7}{16}$ in. diameter galvanised steel wire; from this messenger cable, which is about 20 ft. from the rail level, the trolley wire is suspended by hangers, one of which is illustrated (Fig. 5). Modifications of these hangers are used on curves and as section insulators, but generally the design differs only in detail. The trolley wire is supported by hangers about 47 ft. apart.

The track is laid with rails weighing 70 lbs. per yard, spiked to ties in the manner characteristic of American practice: the joints are bonded with ribbon bonds.

The motor cars are fitted with four 75 h.p. motors capable of operating on direct or alternating circuits, being wound for 220 volts, and operated in series-parallel combination when on direct current, and in parallel only, on alternating current, the trolley line voltage of 3,300 being reduced on the car by an auto-transformer to the lower voltage just mentioned.

As the company operates trains of cars, some of which are motor cars, multiple unit control is employed whether on direct or alternating current. The contactors are just the same as are employed on direct current systems, and our readers are familiar with these from our descriptions of London tube railways, the only modification necessary to make them work satisfactorily

FIG. 5.—ANCHOR SUSPENSION FOR TROLLEY WIRE.

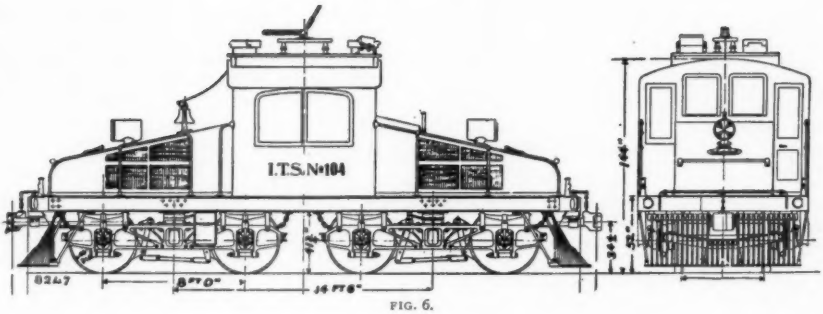


FIG. 6.

on alternating current is that the magnet must have a laminated core, instead of a solid one.

A feature of considerable importance, and one we believe not hitherto used on a line of any importance, is the arrangement for making the control automatically selective, so that the control equipment is instantly adjusted to the new conditions when the train passes from the alternating to direct current supply or *vice versa*. The operating coil of the alternating current circuit switch is supplied from the secondary of a small transformer, hence it is unaffected by the passage of direct current, but the moment an alternating current passes through, it operates and closes the circuit on the alternating current side. The operating coil of the direct current switch is in series with the primary winding of the same transformer, but owing to its high self-induction it is unaffected by the passage of an alternating current, but responds immediately to a direct current.

It is apparent, therefore, that the moment the leading car of a train passes from one system to another, the main switches are opened one side and closed on another, entirely independent of the motor man.

A single-phase electric locomotive for freight traffic on this line is illustrated (Fig. 6). It has four 150 h.p. motors, one on each axle; at full load a tractive effort of 15,000 lbs. is developed, so that it is capable of drawing a train load of 500 tons on a level track at twenty-seven miles per hour. The locomotive has an overall length of 32¾ ft. and a breadth of 9½ ft. It is controlled by a selective system for discriminating between direct and alternating current, just as the motor cars for passenger service are.

A Welsh Colliery Power Equipment.

The Cambrian collieries are among the largest in South Wales, employing about 3,500 men, with an output of one million tons of coal per annum. Some three years ago a trial of electric power was made, supply being obtained from the South Wales Power Company; this proving satisfactory, a more comprehensive scheme was embarked upon, under the advice and supervision of Mr. C. P. Sparks. It was decided to generate their own electric power instead of purchasing it, and two 750 kilowatt, three-phase generators by "Siemens" direct coupled to "Belliss" triple expansion engines have been installed in the power house. Steam is supplied by four 30 ft. by 9 ft. Lancashire boilers working at 160 lbs. pressure, the steam is superheated to 150° F. by "Sugden" superheaters.

Two "Korting" ejector condensers are used, each capable of dealing with 13,000 lbs. of steam per hour, and giving a vacuum of 26 in. There is a small exciter plant consisting of a 55 h.p. "Belliss" engine and direct current

generator, which has a separate condenser of the same type, but capable of dealing with 1,000 lbs. of steam per hour. In addition there are two 70 kilowatt motor generators which supply direct current, part of which may be used for exciting the alternators, supplying current for local lighting and a few motors.

There are about twenty-one induction motors ranging from 3 to 220 h.p., aggregating 1,890 h.p., doing practically all the mechanical work in the colliery.

IRON, STEEL, AND THE FOUNDRY.

Conducted by PERCY LONGMUIR.

Rail Steel by the Continuous Open Hearth Process.—Mr. B. Talbot, in a paper read before the American Society for Testing Materials, describes the production of rail steel by the continuous process at Cargo Fleet. This process has been noted in earlier issues, and it will be remembered that it is a modification of usual open hearth practice, the product as described by Mr. Talbot being "absolutely open hearth steel." Steel rails have been made by the continuous process both from molten pig iron and also from Bessemerised metal fed into the steel furnace. In the latter case, it is purely a question of the cost of Bessemerising and small basic additions, as against the cost of a large quantity of oxidising material otherwise required to convert the crude molten metal. Manifestly a 200-ton continuous steel furnace, when fed with blown metal from the Bessemer converter, will produce a large output of ingots, probably 3,000 tons per week or more. In either case the steel rail made is equally good, as a high carbon, low phosphorus product is obtained. Practical experience also shows that steel from the continuous bath is somewhat less oxidised than steel from the ordinary open hearth furnace; this is proved from the fact that a given weight of ferro manganese will increase the manganese in the steel rather more in the case of Talbot steel than it will in ordinary open hearth steel. Hence less ferro is added to the continuous bath than is required in other open hearth furnace practice. The table on p. 188 gives the results of tests applied to rail steel by this process, and a further feature of interest will be found in a comparision of the analysis of the steel with that of the pig iron from which it was made.

How may Quality of Steel Rails be Improved?—Under this heading in the *Engineering and Mining Journal*, Professor Howe give certain suggestions with a view to improvement. The increase in wheel loads has led to the introduction of harder and therefore higher carbon rails in order to resist abrasion. This increase in carbon intensifies the embrittling effect of phosphorus. Another point is found in high finishing temperatures, and it has long been known that the higher the finishing temperature, within certain limits, the more brittle is the steel. In order to make a rail which shall be safe under the traffic of to-day, this brittleness must be lessened, and as regards phosphorus, either by reducing the total content, or by lessening the embrittling

SCHEDULE OF TESTS OF STEEL RAILS MADE BY THE CONTINUOUS OPEN-HEARTH PROCESS.

No.	Carbon required	Analysis of Steel. C.	Si.	S.	P.	Mn.	Tensile Tests. Tons per sq. in.	Elong. in 3 in.	Reduction of area.	Deflection, in inches, on drop of 1 ton 30 ft.; 3 ft. 6 in. centres. 1st blow, rail upright.	2nd, rail reversed.	3rd, rail upright.	4th, rail reversed.	5th, rail upright.	6th, rail reversed.	7th, rail upright.	8th, rail reversed.	9th, rail upright.	Remarks.	Analysis of Pig from which Steel was made. Si.	S.	P.
1	0·55-0·65	0·59	0·019	0·042	0·037	0·77	51·0	12·0	13·4	3¼	—	3 1/8	—	3⅜	—	—	—	—	Twisted at 6th blow, no fracture	0·89	0·13	2·2
2	0·40-0·50	0·49	0·031	0·046	0·065	0·94	52·6	11·0	9·7	3	—	3	—	3	—	3¼	—	—	Twisted at 9th blow, no fracture	0·93	0·09	2·3
3	0·40-0·50	0·49	0·046	0·04	0·032	0·92	49·7	12·5	11·3	3⅜	—	3¼	—	—	—	—	—	—	Broke on 5th blow	...	0·84	0·116	2·2
4	0·40-0·50	0·46	0·046	0·066	0·026	0·816	42·2	13·0	14·3	3⅜	—	3⅜	—	—	—	—	—	—	Twisted at 3rd, no fracture	...	0·93	0·085	2·4
5	0·40-0·50	0·43	0·04	0·071	0·048	0·736	40·8	18·0	18·7	4⅜	—	4	—	—	—	—	—	—	Twisted at 3rd, no fracture	...	0·76	0·83	2·4
6	0·40-0·50	0·47	0·037	0·038	0·04	0·866	46·0	13·0	16·3	3⅜	—	3 1/8	—	3⅜	—	3 1/8	—	—	Twisted at 7th, no fracture	...	1·17	0·099	2·2
7	0·40-0·50	0·48	0·031	0·029	0·039	0·855	47·3	13·0	15·3	3⅜	—	—	—	—	—	—	—	—	Broke on 3rd blow	...	0·79	0·113	2·1
8	0·40-0·50	0·45	0·05	0·05	0·061	0·716	43·0	15·5	12·2	4	—	3⅜	—	3⅜	—	3⅜	—	—	Twisted at 7th, no fracture	...	0·79	0·09	2·4
9	0·40-0·50	0·44	0·035	0·059	0·036	0·723	40·2	16·0	18·8	4	—	3⅜	—	—	—	—	—	—	Twisted at 3rd, no fracture	...	0·75	0·103	2·3

An attempt was made to test all the above to destruction under the drop test, but with the exception of Nos. 3 and 7, it was found practically impossible to do so, owing to the tough nature of the steel, and the twisting of the sample.

effect of that phosphorus, or by both means jointly. It is improbable that the phosphorus content can be reduced by the use of low phosphorus ores as to yield a safe rail, owing to the insufficient supply of phosphorus free ore to yield the enormous quantity of rail steel needed. The Bessemer process does not effect a reduction of phosphorus, and under American conditions the present procedure cannot be so altered as to effect this removal. The basic open hearth process can readily remove phosphorus so fully that its embrittling effect would no longer be important. This is the remedy of the future: in considering present ones, Professor Howe attaches importance to (1) restraining segregation, and (2) to lowering the finishing temperature of the rail.

Steel which contains as a whole 0·07 per cent. phosphorus may contain in its segregate 0·30 per cent. phosphorus, and though this segregate lies near the neutral axis of the rail, yet even there it is a source of danger. In order to lessen the degree of residual segregation (segregation which remains in the finished rail), the three steps advised are: first, free use of aluminium; second, extremely slow pouring; and third, greater discard from the top of the ingot. Aluminium will materially lessen segregation, but it will lengthen the pipe, or, where no pipe exists, it will increase the tendency to piping. This tendency will in turn have to be met by cropping off and discarding a larger part of the top of the ingot. Extremely slow pouring should both shorten the pipe and raise the segregate towards the top of the ingot, in both respects lessening the proportion of the discard. Slow pouring thus counteracts the pipe lengthening effect of aluminium, which accompanies the beneficial effect of that metal in lessening the degree of segregation.

It is well known that within certain limits the higher the temperature at which the rolling of the rail ends the more brittle will the rail be; and that the power of the rail to endure shock is increased by continuing the rolling until further reduction becomes difficult. In practice the trouble in applying this principle lies in the thickness of the head, which remains hot at a time when the web and the flange have become comparatively cool. After noting the difficulties which lie in the way of an

equal lowering of finishing temperature, Professor Howe passes on to a consideration of the rail section, and it is shown that some alteration would lessen these difficulties. By making the web and flange materially thicker than they now are, the additional metal would permit the rolling of the head to be prolonged till this part had cooled to a safer temperature. From a purely civil engineering standpoint the increased thickness would not be wholly wasted because it would materially add to the rigidity of the rail.

Turning to the question of desiccated blast for converters, various aspects are considered, and it is noted that more second quality rails are made in summer, when the air is moist, than in winter, when it is dry. After eliminating all variables comparatively little importance may be attached to this fact. The better quality in winter is more probably due to other causes, such as the physical condition of the men, and especially the blower, in the bracing weather of winter in contrast with the trying heat of summer.

There remain the electric purifying processes by which phosphorus may be removed. But according to data available, these would be so costly in the present state of development as to be hardly worth considering.

Mechanical Experiences with Limber and Stiff Rail Sections.—Dr. Dudley in a paper read before the American Society for Testing Materials, discusses various factors in the production of rails and their effect on mechanical and wearing properties. For the moment we chiefly note the author's remarks on dessicated blast for the converters in that they present another opinion to that expressed in Professor Howe's paper. Dr. Dudley's records show as a general observation that rails rolled in August and September when there is much humidity in the air, have developed split heads in greater numbers than those rolled during the winter season. The use of refrigerated air, in which the moisture was reduced to a low limit, would be preferable for use in Bessemer converters. Each ton of metal converted requires approximately about 0·6 tons of air to be blown through it, and with a large percentage of moisture it affects the physical properties of the metal by a greater inclusion of gases. The practice followed in many mills using direct metal, of regulating the temperature of the blowing metal by means of a steam jet in lieu of scrap, is decidedly objectionable and injurious to the resulting product.

The Ascendancy of Vanadium Steel.—Writing in the *Mining World*, Mr. Baxeres de Alzugaray indicates the useful field open to vanadium in connection with steel making, and submits that a reduction in price would lead to considerable developments in the application of vanadium. Late quotations of vanadium and vanadates are as follows—per pound :—

Vanadate of iron (32 % vanadium) ...	$1·00
Vanadium ore (12 to 15 %)	·35
Vanadium, ferro (25 %)	2·50
Vanadium, ferro (50 %)	$3·80 to 4·00
Vanadium, ferro (50 to 70 %) ...	4·25 to 7·50

These prices give a reason for the stationary demand for vanadium. To add 1 per cent. vanadium to steel, taking as a basis the prices quoted, would be equivalent to increasing the price of the steel to $250 per ton or eight times the cost of a fine quality steel.

If these prices were based on a scarcity of vanadium ore, there would be some justification, but it is evident that of the special elements used in steel making, vanadium is one of those found in great abundance, chiefly in the inexhaustible seams of highly impregnated vanadiferous sandstone.

The chemical processes used to obtain concentrated vanadium oxide mixed with iron oxide are still very imperfect and will admit of much improvement. These oxides with the addition of suitable fluxing material could be applied direct to the steel furnace in such quantity as would be suitable to impart high elastic modulus and tensile

strength. Operating as is suggested here the saving would be considerable, and the vanadate ought not to sell above 50 cents per lb., exactly one-half of the present market quotation. With vanadium at $2 per lb. excellent steel rails could be produced at an extra cost of from $5 to $10 per ton, and still leave the vanadium producer a considerable net profit.

Material for Automobiles.—Mr. Elwood Haynes in a paper read before the American Society of Engineers traces the early difficulties met with in the steel parts of motor cars. The first nickel steel axle was introduced in 1899 and its success led to considerable development. Not only was this steel found to be free from crystallisation but it possessed a very high elastic limit; about 70,000 to 80,000 pounds; and a tensile strength of over 100,000 pounds with an elongation of 15 to 20 per cent. Nickel steel was also introduced into the construction of driving chains showing superiority over those formerly made of ordinary steel.

Trouble with the sliding gears found a remedy in nickel, chrome steel. This steel may be hardened by heating to redness and quenching in oil, and may then be given a considerable amount of toughness by drawing the temper somewhat after the first hardening. With a well-made and properly treated steel it is almost impossible to break one of the teeth in a six pitch gear by means of a hammer. So successful were these gears that they rendered it possible to run an entire season without breakage or serious injury of a single tooth. Front axles, steering knuckles, and other important parts requiring high elasticity were made of this steel in certain cars with very good results. Vanadium steel by reason of its high elastic limit, strong contraction of area and splendid silky fracture together with the large number of vibrations which the steel endures under dynamic stress is almost ideal for many parts of the motor car. The writer's experiments show that it works well under the hammer and the steel is not readily injured, provided due care be taken not to heat it too rapidly. In discussing the use of bronzes the writer notes that they must necessarily be restricted to parts requiring low rigidity. Whilst samples of bronze can be made to fairly closely approach good grades of steel in tensile strength, elastic limit and contraction of area, it must be remembered that the modulus of rigidity of iron and steel is about 28,000,000, whilst that of bronze is only about 15,000,000. In other words a bar of bronze of a given size and form under given conditions will deflect twice as much under the same load as a similar bar of iron or steel. Finally, in summarising, the author gives the following materials as having proved suitable for the various parts of the automobile.

(*a.*) For rear live axles, nickel steel of from 4 to 5 per cent. nickel with less than 0·30 per cent. carbon.

(*b.*) For front axles, steering knuckles, propeller shafts, &c., vanadium steel.

(*c.*) For sliding gears, nickel chrome steel, hardened throughout, or mild nickel steel case hardened.

(*d.*) For crank shafts nickel steel or vanadium steel.

(*e.*) For frames, low carbon open hearth steel, mild nickel steel or nickel chrome steel.

(*f.*) For nearly all other parts, hand levers, tubing &c., a good open hearth steel of about 0·40 per cent. carbon, is of suitable quality since there is no advantage in using high-class steel for these purposes for the reason that the rigidity of these parts is of prime importance, and in order to make them sufficiently rigid they must be made much more than sufficiently strong; therefore, since all steels are practically equal in rigidity, one steel is broadly speaking, as good as another for these parts.

The use of bronze should be restricted largely to minor parts; the reducing gear wheels; small levers, &c. can be made of phosphor bronze whilst the bearings should be made of a good composition bronze.

LEADING ARTICLES OF THE MONTH—CURRENT EVENTS—TECHNICAL INFORMATION FROM ALL SOURCES.

The Present Position of Gas and Petrol Engines.*

The present position of the internal combustion motor industry in Great Britain is one of sound commercial prosperity. At no previous time have the gas and oil engine builders had so many orders in hand, and never before have these motors been applied so successfully to so many different purposes.

Smooth success, however, is not interesting from the point of view of the scientific investigator or inventor; and, accordingly, I propose to discuss the present position with regard to existing difficulties rather than existing successes.

Engines of small and moderate powers are built in large quantities; their difficulties have been thoroughly overcome and they have attained to an almost fixed type. The larger part of the British gas engine industry is occupied with such motors, generally under 100 h.p. per cylinder. The turnover in Britain at present of such engines is at the rate of some 300 engines per week. It is generally recognised that these engines are as reliable as the best steam engines of similar dimensions and much more economical in fuel consumption. The smaller engines mostly use coal gas, and the larger producer gas evolved by means of modern suction producers using anthracite for fuel.

Large gas engines of English design have also been built in greater numbers, principally by the Premier Co., Messrs. Crossley Bros., Ltd., and the National Gas Engine Co. English designers have always felt the desirability of keeping down cylinder dimensions as much as possible, and in this Continental designers have recently shown a strong tendency to follow them. This trend is due to a more general recognition of two facts: practical difficulties with large diameter cylinders due to unequal expansions resulting in cracking, and a better appreciation of the fact that increase in cylinder and other dimensions requires an increased expenditure in metal and workmanship in greater proportion than increase of power obtained. The large gas engine really presents two distinct problems. The first is to build engines of large power which will continue to run effectively and economically for long periods without breaking down, and the second is to build such engines at costs sufficiently moderate to enable the engines to compete effectively with the large steam engines in the matter of first cost. British engineers have recognised for some time that the first part of the problem has been solved to some extent on the Continent, but many of them have felt that this solution has involved weights of material and costs of construction which are almost prohibitive, considering the moderate powers obtained. In fact, English engineers consider the large gas engine, as it at present exists, both too heavy and too costly for its power. Personally, I do not believe that sound and continued commercial success can be looked for with really large gas engines until some better solution be found for their present constructive difficulties.

Apart from the questions of the engines themselves, there are other difficulties which prevent the equal competition of gas engines with steam engines for powers, say, greater than 400 or 500 horse. Coal gas is too expensive a fuel for large engines. Producer gas, evolved by the suction producer from anthracite, air and steam, effectively meets the wants of medium-sized engines up to 200 horse, but the cost of anthracite handicaps engines of larger size, and equal competition will not be possible until better

* Paper read by Dugald Clerk, M.Inst.C.E., F.C.S., before the meeting of the British Association at Leicester.

bituminous fuel producers are designed than those which at present exist The work on the Continent has not aided the solution of the bituminous fuel producer problem. Practically all the large Continental gas engines are operated with blast-furnace gas. Some success has been attained in Britain as the result of strenuous and praiseworthy efforts by Dr. Mond, Messrs. Crossley and others; but it cannot yet be said that an entirely satisfactory bituminous producer has appeared. In my view, no bituminous fuel producer can be considered really satisfactory until it attains simplicity, lightness, and the fewness of parts of the anthracite suction producer which now forms so large a British industry.

Returning, however, to the engine difficulties, the large gas engine may be considered as combining the difficulties of hydraulic engineering work at considerable pressures with those proper to a boiler furnace or flue. The possible pressures to be resisted by such engines cannot be taken as less than 400 lb. to 500 lb. per sq. in., and a heat flow through the cylinder and combustion chamber walls has to be provided for greater than that of most boiler furnaces. It is obvious that here we have contradictory conditions involved which become rapidly onerous with increase of dimensions. Thick castings are required to stand the high pressures, but to allow free heat flow from the flame within the cylinder to the water in the water-jacket calls for thin castings. Engines of small dimensions do not involve any serious conflict, but where metal is required of about 3 in. thickness to resist internal pressures, the temperature difference between the flame and water side of the metal becomes serious, and great stresses are set up which ultimately lead to the cracking of the castings. Great attention has been paid to this phenomenon of cracking, and in existing large gas engines the difficulty has been partly met by skilful design and special quality of metal used. Although much ingenuity and skill has been spent in this direction, yet it is found that a dimension limit is very soon reached. Cylinders, for example, of 51 in. diameter have been found to be too large. Nothing but the highest skill in designing and the greatest care in the choice of material and workmanship enables such cylinders and combustion chambers to withstand, for any length of time, the severe treatment to which they are exposed.

In a paper which I had the honour to read at the Cambridge meeting of the British Association, I directed attention to the question of the working fluid of these engines, and described experiments which I had made and engines which I had built with the aim of reducing the mean temperature in order to reduce heat flow. Good results were obtained with these engines, but I came to the conclusion that the methods of reducing temperature then adopted did not go far enough. For the last three years I have been attempting to reduce maximum pressures as well as temperature, without reducing mean pressures, in order to diminish the weight of the engines for a given power and to secure moderate thickness of cylinders and combustion chamber castings. There are several ways of reducing temperatures and maximum pressures without reducing mean pressures, but all require much more accurate knowledge of the properties of the working fluid than we at present possess. One solution of the problem appears to lie in compounding, and I am now at work on this. Many attempts have been made to compound the gas engine by Dr. Otto, Messrs. Crossley, Mr. Butler, Messrs. Dick, Kerr & Co., and others, and I myself have also at various times built experimental compound engines. No success, however, has yet been attained. There is no difficulty in getting some work from the low-pressure cylinder, but the additional work obtained was always too small in amount to justify the expense of the separate cylinder. The lack of success was mainly due to ignorance of the rates of cooling of the working fluid at different temperatures and pressures. Experiments made with closed vessels do not give much information on the necessary points. I found it necessary to make experiments of this nature on the engine itself in its working condition instead of on closed vessels. At the beginning of 1905 I designed a new method and performed a considerable number of experiments on a 50-h.p. gas engine, by means of which I obtained a cooling curve in the actual engine cylinder and much other information of a useful nature, both from the scientific and the practical points of view. Fig. 1 shows two sections of this engine. Its action was modified by so altering the valve arrangements that at any desired moment both inlet charge valve and exhaust valve could be held closed, and with this device I was enabled to get diagrams from which a cooling curve could be calculated. One of these diagrams is shown at Fig. 2. It will be seen that the usual charging stroke—compression, explosion and expansion—is performed proper to the four-cycle gas engine; but when the exhaust period

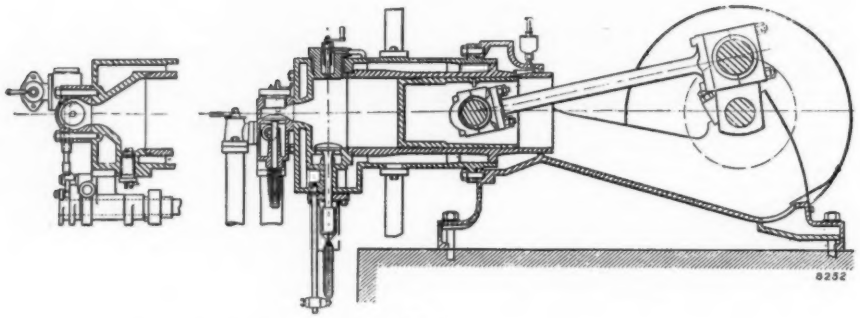


FIG. 1.

approaches, instead of opening the exhaust valve and discharging the gases at the proper point, the valves are all kept closed and no gases are allowed to escape from the cylinder. The energy stored up in the fly-wheel accordingly causes the piston to compress the whole contents of the cylinder into the compression space, and the temperature which had fallen by expansion rises again by compression. A point is touched by the indicator pencil on a vertical line at the compression end of the card. On expanding, a line below the first compression line is drawn; then the next in-stroke traces another compression line. In this way a series of compression and expansion lines are obtained, each terminating under compression at certain specific points. These points are successively lower in order. In this particular diagram it will be observed that before the ordinary compression line of the engine is reached six of these points are marked. If no cooling took place in the cylinder, obviously whenever the volume was restored to any particular point—that is, say, to the volume of the compression space—no fall of temperature would be visible between one revolution and another. The compression and expansion lines would coincide. The fall, as you see, is gradually decreasing from revolution to revolution. This gives an idea of the time taken to lose heat to the cylinder walls with all the engine parts in their ordinary state. The temperature fall from point to point, however, is not entirely due to heat loss. Some of the heat disappears as work done. A certain amount of the heat is converted into work at each reciprocation. This, however, can be allowed for, and a cooling curve obtained which shows the real temperature drop due to cooling upon the expanding and compressing lines. From this curve the apparent specific heat of the charge can be obtained for each expansion line. Tables I. and II. have been calculated from the numbers so obtained. These tables clearly show that the apparent specific heat of the working fluid, which consists of the products of combustion in the cylinder of this particular engine, increases considerably with temperature, so that the instantaneous value is about 28 per cent. greater at 1,000° C. than it is at 100° C., while at 1,500° C. the increase amounts to 31 per cent. The mean apparent specific heat between 0° C. and 1,000° C. is 15 per cent. greater than it is at 100° C.; between 0° C. and 1,500° C. it is 20 per cent. greater. These apparent

TABLE I.—APPARENT SPECIFIC HEATS (INSTANTANEOUS) IN FOOT-POUNDS PER CUBIC FOOT OF WORKING FLUID AT 0° C. AND 760 MM.

Temperature.	Specific Heat at Constant Volume.
Deg. C.	ft.-lb.
0	19·6
300	23·0
600	25·2
900	26·6
1,200	27·2
1,500	27·45

TABLE II.—MEAN APPARENT SPECIFIC HEATS IN FOOT-POUNDS PER CUBIC FOOT OF WORKING FLUID AT 0° C. AND 760 MM.

Temperature.	Specific Heat at Constant Volume.
Deg. C.	ft.-lb.
0—100	20·3
0—300	21·4
0—600	22·8
0—900	23·9
0—1,200	24·6
0—1,500	25·2

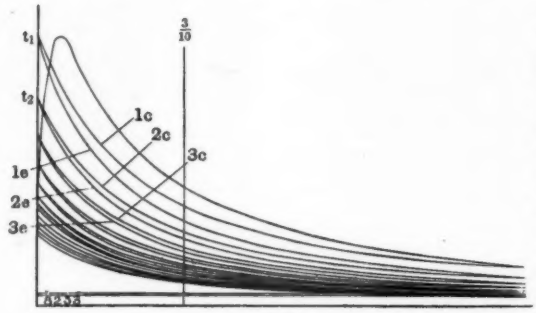


FIG. 2

specific heat numbers enable me to obtain a curve of heat loss to the sides of the cylinder either for complete double strokes or for partial double strokes at the inner end of the stroke. Fig. 3 shows four such curves. The curves (*a*) (*b*) represent the heat losses incurred in complete revolutions—that is to say, in complete double strokes. Here the surface exposed and covered alternately is that due to the whole sweep of the piston. The curves (*a'*) (*b'*) represent losses incurred at the upper three-tenths of the double stroke, while the piston moves from three-tenths stroke to the end, compressing into the clearance space, and then moves out again to the point of three-tenths of the outward stroke. The ordinates give heat loss in foot-pounds to the second and the abscissæ mean temperatures per total stroke or double three-tenths stroke. This table gives interesting information enabling approximate calculations to be made dealing with the durability of the working fluid exposed to cylinder surface. It has enabled also important facts to be discovered as to the mean temperature of the cylinder walls and the heat flow with varying density. Curves (*a*) (*a'*) were calculated from experiments made with the engine running without load at 120 revolutions per minute, jacket water kept at a mean temperature of 13° C. Curves (*b*) (*b'*) are calculated from experiments made with the engine running at 160 revolutions per minute with a load of 150 b.h.p. and jacket water at 80° C. The curves are accordingly marked as "Engine cold," "Engine hot." When the engine is running cold the mean temperature for the complete strokes of the walls is shown to be about 65° C., notwithstanding that the jacket water is 13°. For the three-tenths stroke, running cold, wall temperature 165° C. With the engine running hot, the whole stroke shows mean temperature of walls 190° C.; for the inner three-tenths 400° C. These numbers, giving quantitative values of heat loss for a given cylinder, enable the conditions within the cylinder walls to be realised with some accuracy. In this particular engine the walls of the combustion space are about 1¼ in. thick; and calculating the temperature gradient in those walls for the heat flows, given temperature difference, say, 700° C., between gas and interior of the wall, gives a temperature difference in the metal between the water side and the gas side of 60° C. A temperature difference of 1,000° C. between gas and inner wall gives temperature difference in the metal of 104° C. These differences are accentuated with greater metal thickness almost in proportion to the thickness; thus with the higher temperature to the last calculation a thickness of 3¾ in. wall would give a temperature difference in the metal itself of over 300° C. These numbers throw an important light upon the problem of the large gas engine, and enable me with some confidence to experiment upon the variations of indicator diagram and the transfer of hot gases from cylinder to cylinder required in successful compounding. The experiments show also many interesting and unexpected facts in connection with the behaviour of high temperature working fluid in these engines. Much remains to be done, however, and I am

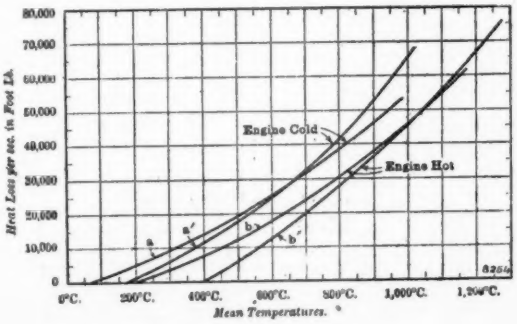


FIG. 3.

continuing the investigation on three engines with the object of determining the laws of the working fluid within the gas engine cylinder more completely.

In modifications of the conditions of the working fluid combined with mechanical modifications of the engine using it, I hope to find in the near future some more satisfactory solution of the large gas engine problem than at present exists. It appears to me that the problem is one more of working fluid than of pure mechanism. So far, however, the conservative attitude of British engineers towards large gas engines has been fully justified. Progress in solving the large gas engine problem has been somewhat slow, but it has been steady. There is no occasion whatever for discouragement, notwithstanding recent difficulties with a large gas engine installation at Johannesburg, of which much has been written in the engineering publications. The difficulties at Johannesburg are, in my opinion, to a large extent due to the daring nature of the experiment undertaken by an eminent firm of engineers whose experience was rather in steam engines than in gas. They very boldly attempted to solve at one stroke the difficulties both of the large gas engine in itself and those peculiar to the bituminous producer. I have no doubt that if they be given time they will solve these difficulties, but the experiment was on too large a scale for most experienced gas engine constructors and designers. I do not attach any importance to this partial failure. It emphasises, what I have always held, the necessity for precaution and much further study in connection with the large gas engine problem. It appears to me, however, eminently unwise and unsafe to attempt to solve the numerous problems involved in too short a time. Gas engine builders must be content with the slow growth of experience and the slower solution of these difficult problems.

As I have already said, part of the large gas engine problem depends upon the producer. A bituminous fuel producer of a type suitable for use on shipboard has not yet been devised, and until such a producer is designed and thoroughly tested the anthracite suction producers of to-day will not allow any great extension of gas motive power to large sea-going vessels. Mr. Capitaine has, I am informed, applied an engine of 300 h.p. to a towing vessel on the Rhine, but as yet this movement is in its early infancy.

The great success of the suction producer in connection with stationary engines on land has enabled the power of gas engines in use to be very materially increased. Tests at the Royal Agricultural Society's show last year have proved that even small producer-driven engines only require 1 lb. of fuel per brake-horse power per hour, including lighting-up and stand-by losses of the producer at night. Other experiments, some of them by myself, show very clearly that with a good suction producer we can obtain 85 per cent. of the whole heat of the fuel in the form of inflammable gas ready for delivery to the engine. Many tests have shown that the running consumption of many of these engines at full load does not exceed $\frac{3}{4}$ lb. of anthracite per brake-horse-power per hour.

In this paper I have not dealt with the question of thermal efficiencies at all. The thermal efficiencies of all gas and internal combustion engines are very high compared with any form of heat motor. In recent tests by the Thermo-dynamic Standards Committee of the Institution of Civil Engineers, an ordinary "National" gas engine gave an indicated efficiency of 35 per cent. and a break efficiency of as nearly as possible 30 per cent. The efficiency obtained from smaller petrol motors is somewhat less, but in tests made by Hopkinson it rises as high as 24·6 per cent. This is a very high efficiency for a small-diameter cylinder.

So far as I understand the question, although large increases in thermal efficiency are still probable, efficiencies are quite high enough at present for all practical purposes, and the main efforts of engineers and scientific men interested in the internal combustion motor should be directed to the solution of the large gas engine problem in such a way as to reduce weight and increase power of the unit; to improve the bituminnous fuel producer: to apply the improved engine and producer to marine purposes and overcome the various difficulties there presented; in petrol engines to design carburetters capable of proportioning the charge more accurately than at present under all conditions of running, whether with light or with heavy loads.

Deep-Well Vertical-Shaft Centrifugal Pumps.

A new type of pump which is of special interest and has already attained an important position in deep-well work is the high-speed centrifugal pump, which is mounted on a vertical shaft and inserted

within the well hole. Particulars as to this method of deep-well pumping are taken from a paper read before the Western Society of Engineers, Chicago, by Mr. C. B. Burdick.

A new pump is entering the deep-well field, and while it seems too much to expect that it will rival the high-duty reciprocating machines, applicable to the lower lifts of the shaft-and-tunnel-method, it has already assumed an important place. The writer refers to high-speed vertical shaft centrifugal pumps of such diameter that they can be set in bored or drilled well holes. It is believed that the earliest application of this device was made in the improvements to the waterworks of Moscow, Russia, completed in 1900. The plant was described by Mr. N. T. Simin, Chief Engineer, in the Proceedings of the American Waterworks Association, 1901. The pump was designed and built by the Forcot firm of Paris. Each pump, as installed, is accommodated in a 16-in. well, and at 1,440 revolutions per minute lifts 812,500 U. S. gallons per day. The lift under which they operate is not specified, but, judging from statements in the paper, is about 50 ft.

In 1902, Mr. John W. Alvord, M.Am.Soc.C.E., prepared a design of an experimental pump, which was constructed under his direction. The pump was so designed that various forms of impeller could be tried, and in 1902, the pump, equipped with the best impeller, showed an efficiency of 50 per cent. when operating at 1,640 revolutions per minute, and discharging 835 gallons per minute against a head of 38 ft. The experimental pump had one impeller only, and so designed as to be accommodated in a 12-in. hole. The experimental pump has been recently turned over to Prof. D. W. Mead, of the University of Wisconsin, who has made a series of tests with various forms of impeller, which form the subject of a bulletin to be issued shortly by the University.

The successful operation of a device of this kind, at high speed, cannot be accomplished without proper provision for handling the down thrust; and the balancing device of Mr. Alvord's pump was one of the most satisfactory features of its operation. Its principle, like most means of balancing, depends upon the head of the discharge water entering around the edge of the impeller, and applying its pressure to the under side of the same. The balancing chamber immediately above the impeller has the office of relieving the pressure from above so that the head below the impeller can act.

It will be observed in Fig. 1 that a duct, *A*, in the shaft connects the balancing chamber, *B*, with the suction side, and that the entrance to this duct is controlled by a port, *C*, that is opened and closed by a slight fall or rise of the impeller and shaft. By this arrangement, as the pump comes up to speed, pressure is produced in the discharge and (by leakage) under the impeller. By the proper apportionment of areas, this pressure tends to raise the impeller and close the port, in the balancing device. The leakage into the balancing chamber from the discharge passage causes the pressure to rise in the balancing chamber in sufficient amount to overcome the up-thrust. In the test it was found that as the pump came up to speed the shaft was lifted about $\frac{1}{16}$ in., and rode clear of the balls in the ball thrust bearing provided at the top of the shaft. Fig. 2 shows this device as it might be applied to very high lifts, the number of balancing chambers being multiplied. The pump is capable of compounding, as is now done in centrifugal pump practice for high lifts. By increasing the number of impellers, high lifts can be accomplished at medium speeds.

The subject seems to have been taken up by Mr. Bryon Jackson, of San Francisco, whose pump, now in operation in several waterworks plants, is in many respects similar to that of Mr. Alvord. The first installation was made under the advice of Professor Mead at the Pabst Brewery at Milwaukee. This pump is a five-stage machine, and is accommodated in a 15-in. hole. It is designed to lift 700 gallons per minute against a net head of 220 ft. The speed of the shaft is 1,300 revolutions per minute, and the pump is engine driven, a twisted belt transmitting the power. The lift at present is 150 ft. Steam cards are said to indicate an efficiency from engine cylinder to water delivered of 56 per cent. It is probable that this means not less than 65 per cent. pump efficiency. A similar installation has been operating at Waterloo, Ia, since 1905.

An interesting electrically-driven waterworks plant just completed at La Grange, Illinois, includes centrifugal pumping machinery for the development of a deep ground-water supply, and subsequent pumping by a second set of pumps into the distribution system of the city. Fig. 3 shows one of the two units installed. The capacity is 350 gallons per minute, with 100 ft. head and at 1,120 revolutions per minute.

The pump is driven by a 25 h.p. "Westinghouse" three-phase, 440-volt induction motor, running at 112 revolutions per minute. It is connected to the shaft by a flexible leather link coupling. The weight of the armature is carried by a separate thrust bearing in the motor casing. A portion of the down thrust is taken by balancing chambers of the "Jackson" type just above the pump runners. It is evidently considered that this balancing arrangement does not have sufficient elasticity, for an additional water step-bearing is provided, on the pump head at the ground level. Until the pump comes up to speed the shaft is carried on a roller thrust bearing on the pump head. In the drawing the well casing is not shown; the pump hanging free and entirely independent of it. The water is discharged through the annular space between the 8-in. uptake pipe and the 3½-in. pipe which encloses the driving shaft. The shaft is supported by babbetted bearings at

intervals of 8 ft. Each alternating bearing forms a coupling for the 3½-in. pipe, and these bearings are centred and held firm by means of three jam-nuts equally spaced around the combined bearing and coupling. Provision is made for giving the bearings and impellers a small amount of oil, but since the first few weeks of

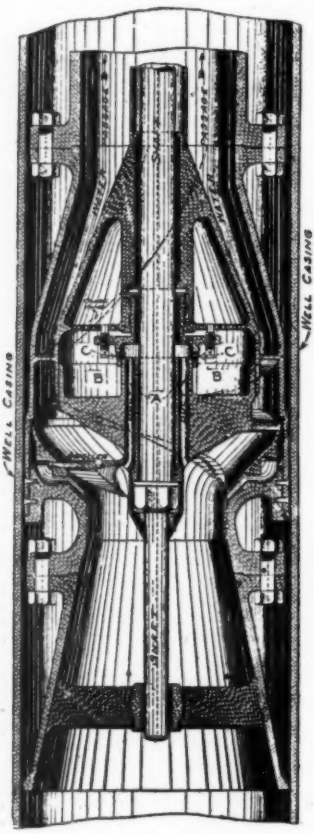


FIG. 1.—SECTION OF DEEP-WELL CENTRIFUGAL PUMP.

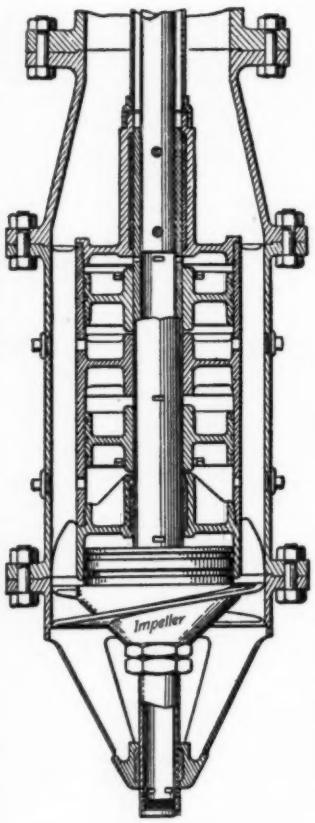


FIG. 2.—DEEP-WELL CENTRIFUGAL PUMP FOR HIGH LIFTS.

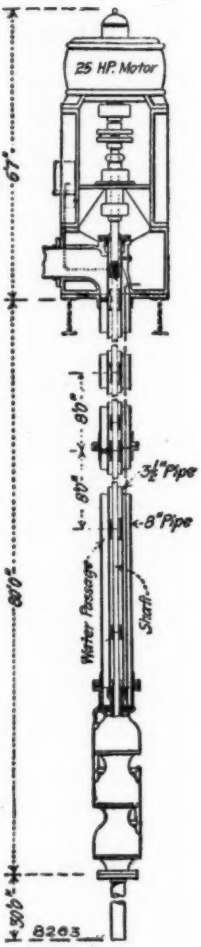


FIG. 3.—ELECTRICALLY DRIVEN DEEP-WELL CENTRIFUGAL PUMPS AT LA GRANGE, ILL.

operation no oil has been supplied except to the impellers, the water lubrication apparently being sufficient. Each pump is now working, when operated alone, under about 75 ft. head, friction not included, and delivers 405 gallons per minute.

The preliminary run seems to indicate that the punp efficiency is close to 50 per cent. and the motor efficiency 85 per cent. The unit in well No. 1 has now been in constant operation for about eight months. The unit in well No. 2 has just been installed. The pump operates very nicely. When in the room with the pump, one has almost to stand directly in front of it to perceive that it is running. The entire pumping plant was designed and built by the Byron Jackson Machine Works, Oakland, California.

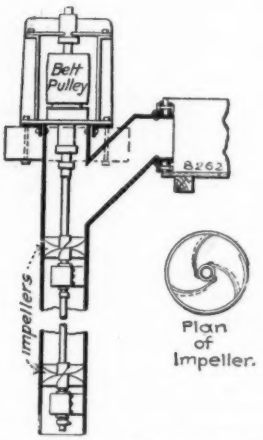


FIG. 4.—DEEP-WELL CENTRIFUGAL PUMP

Reference must be made to the propeller pump designed and built by Mr. P. K. Wood, of Los Angeles, California. It is believed that the use of this pump antedates the "Moscow" installation. Fig. 4 is an illustration of this pump, which sufficiently explains its method of operation. The propellers are shown equally spaced, the lowest impeller, of course, being below the static water level of the well. Mr. Wood discovered that these propellers may be compounded, and when bunched at the bottom of the shaft the result is the same as by the arrangement shown. Professor Turneaure tested one of these pumps at Madison previous to the permanent installation of the city waterworks, and reported the overall efficiency of the driving electric motor, belt and pump at 40 per cent. He estimated that, allowing for motor and belt, the pump efficiency is about 50 per cent. With some improvements in its mechanical details this pump should give a good account of itself.

Ventilation of Workshops and Factories.

The Departmental Committee appointed in 1900 by the Home Secretary to inquire into the ventilation of factories and workshops has just issued its second report, which has been published as a Blue Book. The report deals more particularly with the removal of dust, fumes, steam, and other impurities associated with special manufacturing processes, and has been prepared with a view to furnishing some general guidance as to the application of fans for this purpose.

Low Pressure Fans.—When air requires to be moved against very slight pressure, the so-called propeller fan is usually employed, although low resistance centrifugal fans can also be advantageously used in some cases. In the propeller type of fan the blades are arranged similarly to those of the screw propeller of a steamship, the air being driven forward by their revolution. By this means enormous volumes of air can be delivered through the fan with a very small expenditure of power, provided there is little or no resistance on either side. For a good type of propeller fan working under practical conditions, with unimpeded flow of air, Mr. W. G. Walker gives the following convenient formula as the result of a number of experiments:—

$$\text{H.P.} = \frac{Q^3}{D^4} \times 0{\cdot}0000115;$$

Where Q = quantity of air discharged in cub. ft. per sec., D = diameter of fan in ft.

The air-delivery by a propeller fan varies in direct proportion to its rate of revolution, while the power needed to drive it varies as the cube of its velocity. Hence for a given expenditure of power much more air is propelled with a low than with a high rate of revolution. In practice, however, it is best to run a fan at a considerable velocity; otherwise the flow of air may easily be greatly diminished, or even reversed, by the influence of wind. With increasing resistance the air delivered by a propeller fan rapidly falls to almost nothing, although considerable power is being expended in driving it. The waste of power is due to the fact that air passes back through the centre of the fan, where the velocity of the blades is low, and the work done by the tips of the blades is absorbed in merely expelling this same air.

The resistance may be due (apart from the influence of wind or of insufficient inlet openings to the room) to constriction of the ducts, inlets, or outlets connected with the fan, to sharp bends or rectangular junctions with branch ducts, and to friction along the sides of ducts. If the sectional area at any part of a duct conveying air to and from a fan be reduced to less than the sectional area of the fan, it is evident that the linear velocity of the current at this point will be correspondingly greater than at other points in the duct. But the work expended in setting air in motion varies as the square of the velocity, and any considerable narrowing of a duct thus introduces a resistance which a propeller fan cannot overcome, with the result that the power applied to the fan is wasted. It is a common mistake to suppose that by constricting a duct leading to or from a propeller fan a materially greater velocity of air current can be obtained. The influence of the constriction is simply to diminish the flow of air. Another source of resistance is any sharp bend in a duct. A rectangular bend

practically doubles the pressure needed to merely set the air in motion in the duct, and a rectangular junction with a branch duct has a similar effect. A loss about half as great also occurs at the inlet opening of a duct unless it is trumpet shaped. Resistance due to friction along the walls of a duct is proportional to the total internal surface of the duct, and to about the square of the linear velocity, but inversely proportional to its sectional area. It becomes a serious item if long and narrow ducts are employed, and such ducts should always be avoided where propeller fans are used. Frictional resistance depends also upon the roughness of the internal surface of a duct, and these surfaces should be as smooth as possible. The narrowing of ducts by deposits of dust should also be carefully avoided, and the better to ensure this, when ducts are being constructed ample provision should be made at suitable points for the easy removal of dust and other accumulations.

High-Pressure Fans.—Where air currents of high velocity are needed, as, for instance, in exhausting the dust from wheels used in dry grinding, or where narrow or tortuous ducts cannot be avoided, it is necessary to have fans capable of working effectively against considerable resistances. For this purpose centrifugal fans are usually employed. In the centrifugal fan the air inlet is at the centre of the fan, which is enclosed in a metal case, and the air driven outwards in a tangential direction by the revolution of the blades into a space between their periphery and the case. A trumpet-shaped prolongation of the outlet increases the efficiency of an exhaust fan.

According to the details of construction, centrifugal fans may be suited to deliver, with a given expenditure of power, either large volumes of air against a relatively low resistance, or smaller volumes against a relatively high resistance; and in selecting a fan, the volume of air required, and the resistance against which it has to work, must be carefully considered. Centrifugal fans suited to work against the higher resistances have also a relatively high internal resistance, so that if they are set to work against a low-resistance in ducts, &c., the energy is wasted on the internal resistance.

The resistances which have to be overcome by pressure fans are of course due to the same causes as in the case of propeller fans; but in practice the factors involved often differ in relative importance in the two cases. Thus the ducts connected with a pressure fan are usually longer in proportion to their cross section, so that resistance due to friction is more important. There may also be many unavoidable bends in them. They are usually best made of metal pipes with smooth internal surface, all sharp rectangular bends or junctions being avoided and no leakage permitted: unless these points are attended to, resistance due to friction, &c., may mount to a very serious extent. On the other hand the comparatively small resistances due to such causes as wind-pressure, restricted inlet openings to a room, &c., are of much less importance that when a propeller fan is used.

The report proceeds to deal with quantity of air required, its proper distribution, and the arrangement of inlets and outlets, all of which are points ably elucidated by examples in a well-illustrated appendix.

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Working Stresses and Working Factor of Safety in Structures.

An interesting discussion on the factor of safety has recently appeared in Bulletin No. 10 of the Engineering Experiment Station of the University of Illinois in Professor A. N. Talbot's *résumé* of Tests of Concrete and Reinforced Concrete Columns.

In view of its wide application of current interest to engineers in general, this subject has been here reproduced.

The real basis for a working stress or a factor of safety to be used in designing seems not to be generally understood, or at least it is not often properly explained, and expressions sometimes heard indicate that the purpose and use of factor of safety and working stress are misinterpreted. Of course, no engineer will say that for a factor of safety of, say, four (using the term factor of safety as based upon the ultimate strength of the material) the structure will take four times the assumed load without injury. It is understood by engineers that the actual ratio of the load which the structure may properly take under the ordinary conditions of construction to the assumed load used in the calculations made in the design is not large and may, under some circumstances, not be very much above one. Yet the statement is sometimes made, or the inference may be drawn, that because a given working stress is to be used in the calculations there is no advantage in looking into the behaviour of the material or the action of the structure at a stress higher than the assumed working stress. It may, therefore, be well to consider some of the aspects of working stresses and factors of safety.

Mild steel has a rather definite elastic limit and yield point, beyond which the character of its action changes in a marked way. Beyond the yield point the rate of stretch in tension becomes almost at once one hundred or more times as much as it was within the elastic limit. In compression, the ultimate strength of mild steel is not far beyond its elastic limit. It is evident that a structure made up of this material will distort and fail when a load producing stresses not much greater than the elastic limit

is placed upon it. The elastic limit of mild steel has a small range, its value running from 50 per cent. to 65 per cent. of the ultimate strength, depending upon the size of the piece, method of rolling, &c., and the steel is made under such conditions that little risk is taken in choosing a value for a particular size and shape of piece. The modulus of elasticity of steel is also quite uniform. It may be said then, that the properties of this material, with proper inspection, are fairly definitely known. When we base the factor of safety of a structure upon ultimate strength of mild steel, whether we do it consciously or unconsciously we have tacitly assumed that the factor of safety named in the calculations is nearly double the factor which will bring actual failure under the conditions assumed to exist in the structure.

For a plastic material, or a material not having a definite elastic limit, or at any rate one for which the stress varies directly as the deformation for at best only a small part of the ultimate strength of the material, a different consideration must be given. For such materials, the effect of lack of uniformity of the material, the effect of increased deformation, of repetitive loading, of time, and of other factors must be considered.

But there are other considerations which go to confine the working stress, particularly in concrete, to the low value usually assumed. Sometimes the stress is made low to allow for a possibly greater load than that assumed, or for a load applied other than statically. Even if the assumed load has the correct total amount, the following items may be said to influence the choice of a lower working stress: (1) Uneven distribution of load among members; (2) Unconsidered stresses due to settling, variability of the material, &c.; and (3) Variation in the material and in its fabrication.

(1) Even with a load of the amount assumed, the division of this load among the members of the structure may be uneven. Variations in stiffness, differences in quality of adjacent members due to inherent variations or to the variations which arise in such a material as concrete during fabrication and setting, differences due to restraint or lack of restraint at connections—all go to make the actual distribution of the load different from its assumed division among the members. In a timber trestle bridge, the weaker stringer is generally less stiff than its stronger neighbour, and hence the poor stringer takes a smaller share of the load and the good one a greater. Even in steel building construction, differences in rigidity of connections, modifications made to overcome lack of exact fit, and variations caused by field riveting act to modify the division of the load. In concrete construction the variations in fabrication and conditions of setting (*e.g.*, in the beams and girders) and the consequent variable effect on stiffness and restraint may have a considerable effect upon the division of the load. This is especially true in the floor, beams, and girders, so that the load transmitted to a particular column may be quite different from that assumed.

(2) Settling of the foundation of one column more than of another is possible. A variation in the shrinkage of adjacent columns through variation in conditions attending fabrication or to a less extent in porosity or stiffness of column will modify the distribution of the load. Variations in size also affect this distribution. The more nearly uniform the dimensions and physical properties, the more nearly regular the division of load will be and the higher the allowable comparative working stress. In this respect, steel is an advantageous building material.

(3) The values of physical properties usually quoted are average values. The data were obtained from test pieces, sometimes large, frequently small, and these may be said to have been made and tested under favourable conditions. Since the members of a structure which have the poorest quality may have a controlling influence upon the amount of load to be carried, if average values are used the factor must be greater to allow for this. In other words, in poorly made beams or columns the load or stress which comes on the piece is relatively near the point of failure than is indicated by the use of the assumed working stress and an average ultimate value.

Enough has been said to show that the assumed stresses are not the actual stresses coming upon the members of a structure and that the relation between the assumed working stress and the average ultimate strength of the material is a matter which should involve thought and study. It may then be stated that (a) the stress actually brought upon a member of a structure by an assumed loading may be materially higher than the assumed working stress, and (b) the stress actually developed in a member may be much higher comparatively (*i.e.*, with respect to its own ultimate strength) than even this increased amount would indicate. This goes to show that the nature of the action of the material, including its stress-deformation relation, should be studied at points well above the assumed working stress. What point should be fixed upon as a basic point, upon which a working factor covering uneven distribution of load, uncertainty of quality, effect of repetitive loading, &c., may be based, will depend upon the nature of the material and the condition of the structure.

NOTES AND COMMENTS.

Either-side Brakes.

In April, 1906, the Board of Trade appointed Lieut.-Col. Yorke, R.E., Mr. Richard Bell, M.P., and Mr. Robert Turnbull to be a committee to examine and test appliances designed to diminish danger to men in railway service.

At their first meeting it was arranged that the question of either-side brakes for railway wagon stock should be considered, and after numerous examinations of models and full-size fitted wagons, have issued a report.

The side-lever brake commonly in use falls into one of two types, viz., rack brakes and pin brakes; in the former, the lever when applied engages in a rack, and is thereby held in position; in the latter, the lever is secured by means of a pin, which has to be inserted by hand through the holes in the lever guard. The design of these brakes, though crude, possesses not only the merit of simplicity, but also the further advantages (1) that the mere weight of the lever when dropped affords sufficient pressure on the brake blocks for general braking purposes, and (2) that the smallest movement of the lever in the upward or downward direction produces a corresponding change in the pressure on the blocks, so that the pressure can be instantly graduated. When the greatest pressure is required, the lever can be pressed down to the fullest possible extent, either with or without the use of a brake stick, and is then secured by engaging in the rack, or by means of a pin. When so held, the elasticity of the lever is of value, in that it tends to prevent the wheels from skidding, and takes up (within limits) the wear of the blocks. The objection to such brakes lies in the lack of means of applying them on both sides of the wagon, which involves the shunter crossing from one side of the line to the other at great risk, as the returns of accidents reported to the Board of Trade amply show.

The problem involved, then, is, while retaining the side-lever type, to devise a brake that can be applied or released from either side.

The conditions which were considered essential were thus stated: "Ease of application; ease on release; security in locking the brake after application, although subjected to such shocks as may be incurred in working; means of holding off the brake under similar conditions; uniformity in the position of the levers on both sides of a wagon—namely, on the right side of a man when facing the wagon; simplicity of design; and sufficiency of braking power." Such would not appear to be difficult of solution, yet the fact remains that of fifty-one models and sixty-nine full-sized brakes submitted for examination not one, in the opinion of the committee, was considered sufficiently satisfactory to warrant their recommending it for general adoption.

The fact that appears to have impressed itself most vividly on the members of the committee during the trials is that all either-side brakes of whatever description, worked by levers acting simultaneously on both sides of the wagon are open to the objection that injury may result to a man engaged on one side of the wagon, by the movement of the lever made by another man in applying or releasing the brake from the opposite side of the wagon, each being in ignorance of the other's presence.

Being faced with the fact, however, that the need of a brake capable of being applied from either side is greater than that of a brake which can be released from either side, the committee have stipulated for the general adoption of a brake which can be applied from either side; in other words, that all wagons must have two brakes of the ordinary kind instead of one. The recommendations are thus embodied in the report:—

"(1) All wagons constructed after a certain date (say, three months from the date of the rule) shall be fitted with a brake lever on each side in the 'cross-cornered' position, in such a way that sufficient brake power can be applied to the wheels by either of such levers. (2) All wagons which are at present fitted with a brake lever on one side only shall, within a period of seven years from the date of the rule, be fitted with an additional lever in the 'cross-cornered' position on the other side, in such a way that sufficient brake power can be applied to the wheels by either of such levers, and all wagons which are at present without brakes shall be fitted with two levers in a similar manner within the same period. (3) All wagons at present fitted with a brake lever on each side in the 'single-ended' position shall, within a period of ten years from the date

of the rule, have the levers re-arranged in such a way as to comply with the conditions in 1 and 2; and (4) No wagon for service to be fitted hereafter with an either-side brake as defined at the commencement of this report, unless it has been approved by the Board of Trade on the advice of this committee. We also suggest that the Board of Trade should reserve to itself the power of granting an extension of the periods mentioned in conditions 2 and 3 to any company or owner whose application for such extension is considered to be reasonable."

Substitutes for Petrol.

The Fuels Committee of the Motor Union of Great Britain and Ireland, under the chairmanship of Dr. H. S. Hele-Shaw, F.R.S., which was appointed "to enquire into the recent alarming rise in the price of petrol, and to report what steps, if any, can be taken to protect the interests of the private consumer," has now completed its labours. The work done by the committee is of the highest importance, and their report contains many facts and figures of the utmost value.

An important conclusion arrived at by the committee is that, owing to the demand for petrol increasing at a greater rate than its rate of increase of supply, a famine in this spirit may take place in the near future, and this view is supported by eminent authorities on the subject, whose opinions are quoted in the report. Of course, new and unexpected sources of supply may be opened up, but geologists, who can speak on this subject with more assurance than in the case of most other mineral products, hold out very little hope of this, and even these must in time become exhausted. As the demand for petrol continues to increase, it is well to consider, in view of the above mentioned possible shortage, the introduction of efficient substitutes for petrol. The committee have carefully considered the alternative fuels available and examined many witnesses on the subject, and they are of opinion that the one affording the greatest promise is alcohol, the supply of which is practically inexhaustible. The restrictions to its use, however, owing to the heavy duties imposed by the excise authorities, and its present cost of manufacture, have prevented its general adoption as a fuel for power purposes in the United Kingdom. In other countries such as France and Germany, the Government encourages the production of this spirit.

The great obstacle in the way of securing a reduction in the restrictive tax on alcohol is the view of the excise authorities that such a step would be accompanied by the illicit use of alcohol for potable purposes; but it may be pointed out that the use of an efficient denaturant would overcome this objection.

Other possible substitutes for petrol, which have been considered by the committee, are heavier spirit, paraffin, naphtha and benzol, but the supply of these when exhausted cannot be replaced by any known process, whereas alcohol, being derived from vegetation, may be produced in any desired quantity.

The following is a summary of the recommendations of the committee:—

1. That, being of opinion that the introduction of alcohol as a fuel in the future is by far the most promising substitute for petrol, they recommend—(*a*) that steps be taken to remove the restrictions on alcohol; (*b*) that a prize be offered for the best essay on alcohol as a fuel; (*c*) that trials be held to test the comparative merits of alcohol and petrol. 2. That the use of heavier spirit be encouraged. 3. That efforts be made to modify the present restrictions on the use and distribution of petrol. 4. That competitions for paraffin carburetters and vaporisers be organised. 5. That benzol, being a home production and more economical in use than petrol at the present time, be encouraged for use in motor cars. 6. That a standing Fuels Committee of the Motor Union should be appointed for the purpose of giving effect to these recommendations.

The fifth recommendation is important. Benzol is a home production and its use should be encouraged, particularly at this present time when the difference between the prices of petrol and benzol is very small. There are firms in this country who are willing, should there be a largely increased demand for benzol, to erect benzol recovery plants in connection with coke ovens and similar appliances for the treatment of coal; the erection of such plants would mean within twelve months an increase of benzol produced in this country of approximately five million gallons per annum, which is equal to doubling the present supply.

Fire Engine for the Great Northern Railway. A new steam fire engine, which has been purchased by the above company, has just been tested at the Doncaster works with satisfactory results. It is one of Messrs.

Merryweather's well-known "Greenwich Gem" type, capable of delivering 450 gallons per minute, and was selected on the recommendation of the Great Northern Railway locomotive engineer, Mr. H. A. Ivatt. The engine can be drawn by horse or hand to any part of the extensive works, or placed on a truck and run to any portion of the company's system where its services may be needed. It can throw as many as four powerful jets simultaneously, and should render a good account of itself if called upon for duty.

NEW MACHINERY AND APPLIANCES.

The Editor cordially invites early particulars of New Machinery, Improvements, Novelties, &c., for inclusion under this section.

The "Smith" Slotting Machine—A new Departure in Metal Slotting.

The accompanying illustration is that of a machine embodying a new principle in slotting, namely, the utilisation of a milling cutter to which is imparted an oscillating movement.

The work is first drilled out by jig to remove the bulk of the stock, and the machine then finishes the slotting in one simple and quick operation, leaving no rough surface on the inside or edges of the slot.

By this method it is claimed that greater accuracy and greater speed is obtained than with slotting machines or other tools hitherto used, as no chipping, filing or broaching is involved. Such work, therefore, as the cutting of cotter holes in piston and connecting rods, motor parts, boring bars, usually carried out on a slot drill, or the cutting of square, hexagon and other symmetrical holes required for sliding gears, solid head spanners, piercing dies, &c., involving the operation of broaching, appear to be well suited to this machine.

The fundamental idea involved is the application of the form-milling cutter to internal work, which has hitherto appeared impossible on account of the arbor preventing any ordinary milling cutter from penetrating to a depth sufficient to enable it to reproduce its own cross section. This difficulty has been surmounted by eliminating the arbor, and substituting, as above mentioned, an oscillating motion for the usual rotary one.

The special form of cutter adopted, consists of a circular body, the toothed portion of which is something less than a complete circle, and is of the requisite cross-section to correspond with the particular slot to be cut. The opposite faces of the toothed portion of the milling disc are toothed near the edge, as is usual in rotary milling tools. The cutter is fitted with a carrying shank by which the tool is clamped in the dovetail shaped recess in the front of the head of the machine, as shown. The shank is of such a length that the centre of the cutter exactly coincides with the axis of the machine spindle; it follows, therefore, that when the spindle and head are made to oscillate rapidly the cutter also vibrates freely about its axis, as though it were on an arbor. There being no arbor actually present to form an obstruction, sinking cuts of very considerable length can be taken.

The degree of oscillation necessarily varies with the depth of slot, for example, the degree of oscillation will have to be less for a deep slot than for a shallow one in order that the shank of the tool, as the slot is being cut through, may not strike the ends of the slot at the upper part. For the same reason the part of the shank adjacent to the cutting disc is reduced in width.

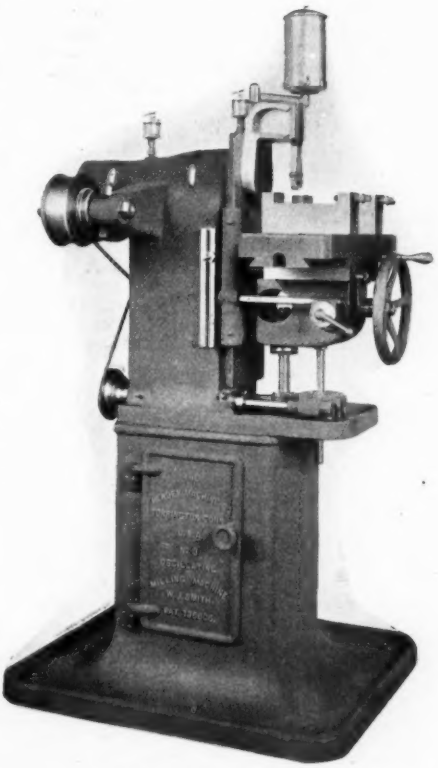
Oscillating movement is imparted to the spindle, crank arm and tool by means of a crank attached to the back end of the spindle, the crank being joined by a connecting rod to a crank-pin on the belt pulley shown. The extent of throw, corresponding to the degree of oscillation, is varied by means of the crank-pin which is eccentrically mounted on a disc, itself eccentrically mounted in the end of the pulley, so that it may be angularly adjusted by partial rotary movement on the pulley to different positions and be clamped in its adjusted position. Variations in throw are possible from $\frac{1}{8}$ in. up to 3 in.

The work is fed to the tool by a feed motion such as is commonly employed on milling machines, hence it calls for no particular mention.

The cutter takes only a light cut, is well lubricated and oscillates at a speed of about 800 oscillations per minute. It is stated that in practice a large number of holes can be finished in suitable material before any appreciable variation in size is caused by wear of the cutter.

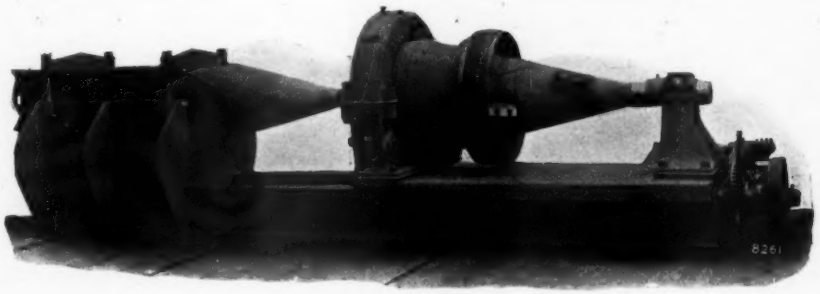
The action of the latter removes the necessary amount of metal without subjecting the material to the crowding inseparable from broaching or drifting operations. Several slots can therefore be made in close proximity to one another, without interference or difficulty of any kind. Further, the operation being free from forcing action, internal stresses in the metal are not set up. This is a matter of importance in the case of such pieces as need to be hardened, and which are apt to crack after much valuable work has been expended on them.

The work is finished by a single passage of the cutters, and therefore compares very favourably with alternative methods, with regard to quickness and low cost, as well as in the high quality of the work produced.



THE "SMITH" SLOTTING MACHINE.

As an instance we may mention that a $1\frac{1}{4}$ in. hexagonal hole was cut in the presence of our representative, through $\frac{1}{2}$ in. rolled special steel angle in just $5\frac{1}{2}$ minutes.



PILE TAPERING MACHINE.

The machine being electrically driven an ammeter was placed in circuit which indicated a maximum current consumption of 3 amperes at 220 volts during the operation. The capacity of the machine, which is made by the Smith Slotting Machine Co., Ltd., 1, Temple Avenue, E.C., is for slots; maximum, 1 by 4 by 3 in., and minimum $\frac{1}{8}$ by $\frac{1}{2}$ by $\frac{1}{8}$ in.

Pile Tapering Machine.

The usual method of tapering piles by hand involves, as is well known, much time and expense. A machine, however, has now been introduced by Messrs. Thos. Robinson & Son, Limited, of Rochdale, for performing this work, and is illustrated on the previous page.

This particular machine is built to work fir piles of 20 in. square, which are placed horizontally and clamped to the bed. The tapering is done by cutter blades in the conical head, which is steadied by an ordinary gearing at one end and by a roller-bearing arrangement at its larger end. This head is driven by belt on a pulley solid with the cone. The whole tapering head is arranged on a slide which is fed forward by belt-driven gear, shown at the right-hand end of the machine. The end of the pile is provided with a suitable support, which is of adjustable height, in order that different sized piles may be accommodated in the machine. The time taken to cut this taper is 15 minutes for each pile. When thus reduced the piles are shod with iron shoes. This particular machine has been constructed to the order of Mr. C. Koning, junr., agent for Messrs. T. Robinson & Son, in Holland, and is for the Rotterdam Harbour Works.

Cross-Slab Partition Construction.

The problem of partition wall construction involving neither the use of plastering nor of grouting, with the consequent absence of moisture, has for some time been exercising the minds of constructional engineers and builders. The attainment of this object has been reserved, however, for a Continental inventor, who has devised a cross-slab method of construction by which the *desiderata* above mentioned have been obtained.

The slabs used in this method of construction are cruciform in shape, the arms being of equal length and thickness. These slabs not only adjoin along a straight line of contact, but they grip each other at right angles and interlock, additional cohesion being obtained by corresponding notches and grooves provided in the angles and along the arms as shown in Fig. 1. Hence it is claimed that a partition wall erected with these slabs is perfectly strong and rigid in all directions and girders can be completely dispensed with (Fig. 2).

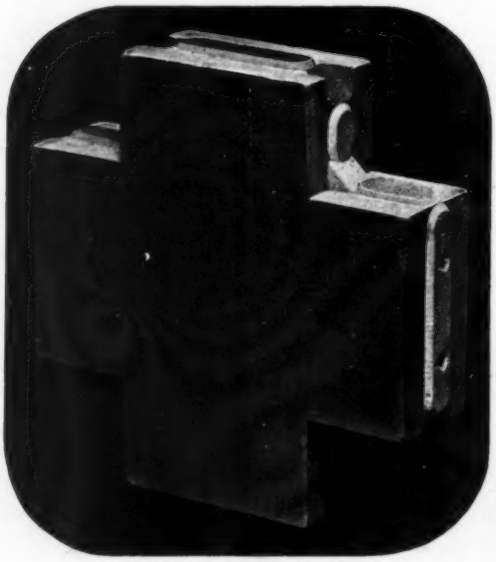
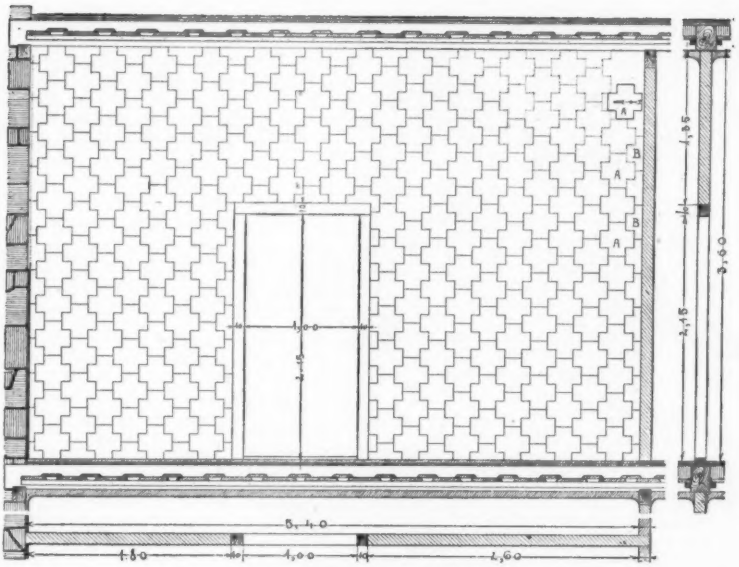


FIG. 1.—CROSS-SLAB PARTITION CONSTRUCTION.

Hitherto these slabs have been made in gypsum, but concrete or any composition capable of producing an accurate and smooth slab may be used and the partitions will thus possess all the additional qualities inherent to the material used, such as being fireproof.

A perfectly level base is the only essential required for the erection of a cross-slab partition, and, if necessary, a ground joist of oak will serve the purpose. The construction of a wall is of the simplest nature and illustrated in Fig. 2.

The door frames which must have the same depth as the partition are nailed against the latter. The



CROSS-SLAB PARTITION CONSTRUCTION (FIG. 2).

fixing of the cross-slab partition against walls or ceilings is done in the usual manner. Where two partitions meet the arms of the crosses dovetail. Should any of the joints of the partition show slight unevenness it can easily be removed by scraping which will secure a perfect surface that can be papered immediately.

The dimensions of the slabs are as follows: Length and breadth 30 cm., breadth of arm 15 cm.; length of arm 7½ cm.; thickness 6, 7½ or 10 cm.

Compression trials carried out with plaster slabs of 30 by 15 by 10 cm., and 30 by 15 by 7½ cm. section showed that the total resistance in the one case was 6·28 tons, equivalent to 42 kg. per sq. cm., and in the other case 5·68 tons equivalent to 51 kg. per sq. cm.

With assembled units giving a total surface of 290 sq. cm., the total resistance was 33 kg. per sq. cm. in one instance and 35 kg. per sq. cm. in another.

The system is being exploited in this country by Mr. Chas. Ingram, of 26, Mark Lane, E.C.

Absorption Dynamometers.

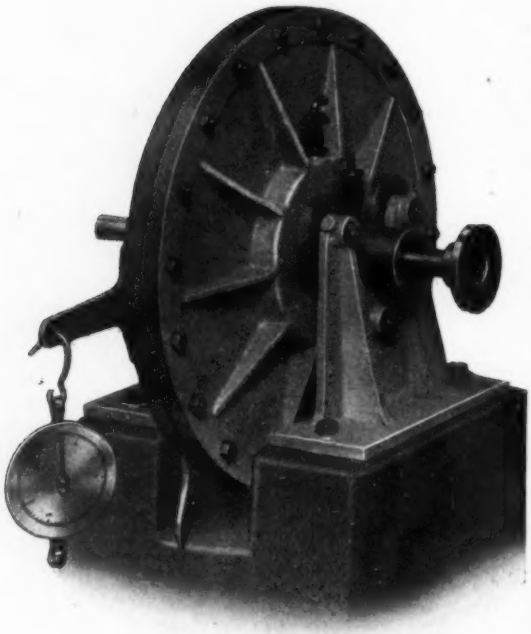
This form of dynamometer has been designed to supersede the unreliable and crude brakes of the "Prony" type, and at the same time to avoid the necessity of external appliances, and consequent complications of calibration associated with electrical and other forms of absorption brakes.

As regards electrical testing sets, those most extensively in use require external resistances, volt and ammeters, for the proper adjustment and reading of the load, and all types are liable to damage and deterioration of armature windings, brushes, &c. Correction, also, has in some cases to be made for heat losses and the efficiency of the machine at various loads.

In the present form of brake, there is no part liable to injury through neglect or rough usage, and the only external fittings required are flexible pipes for oil or water supply, and a spring balance. Further, all the work given to the brake is definitely recorded, and no losses have to be reckoned.

The apparatus depends in principle upon the action of skin friction between plates and moving fluid, and consists of a cast-iron casing, carrying long trunnions supported on friction discs or ball bearings, about which the casing is free to rotate within limits.

An arm is attached to the casing to project to a fixed distance from the centre, and carries a spring balance to register the turning effort of the casing. The shaft



ABSORPTION DYNAMOMETER.

uns in bronze bushes in the trunnions, and carries one or more smooth discs of steel plate, of a diameter sufficient to occupy nearly the full diameter of the interior of the casing, and between each pair of plates is a ring of similar plate fixed in the joints of the casing. The fixed and revolving discs are separated, and never come into contact. The brake is partially filled with water, and on the discs rotating, the water is carried out to their extreme edges, rotating with the discs, but at a lower speed. The energy of the motor under test is entirely dissipated by the friction of the fluid against the fixed and moving plates. The movement of this friction force tends to rotate the casing about the trunnions, this effort being measured by the spring balance fixed to the arm. It is evident that any friction of the fluid or in the shaft bearings is duly shown on the spring balance, and the readings there always give a true record of the work given in to the brake.

The fluid is introduced at the centre of the casing, through a regulating cock, and shown drawn off at the rim. The quantity of water is adjusted, when the brake is in use, by a tube which may be set to project inwards to any point towards the centre of the shaft. The water inside this radius is discharged by a centrifugal force, thus regulating the depth of the ring of fluid round the periphery of the discs. With a given quantity of water in the casing, and at all but the lowest speed, the torque on the casing bears a fixed relation to the speed of rotation of the shaft, so that by increasing or reducing the water contents any condition of torque and speed can be obtained. The adjustments are made when running with ease and certainty, and prolonged runs at any load may be made without attention to the brake, a constant flow of water being adjusted, whereby the heat generated is carried off. The load is remarkably constant, and the brake tends to keep the speed perfectly steady, as, since the resistance varies rapidly with any change in speed, moderate variations in driving power have little effect in altering the rate of revolution.

This brake, it will be seen, is specially suitable for the testing of petrol motors and the like, but its uses extend to the testing of motors of all classes. It is self-contained and independent, and may be made portable, and be used anywhere, provided only that a supply of oil or water is available. For runs of short duration continuous circulation of water is not required. One convenient size of brake, for example, is suitable for any speeds between 300 and 1,200 revolutions per minute, for maximum torques representing 12 and 50 b.h.p. respectively. This, however, is only one of a large range of types, suitable for any desired range of speeds and loads. By changing the number of discs, brakes for any required power can readily be built up.

The maker is Mr. Peter Brotherhood, Belvedere Road, Westminster Bridge, S.W.

THE ENGINEERING PRESS.

In this section is presented every month a list of the more important articles appearing in the Engineering Press and of the leading papers read before the various engineering institutions. Full names, addresses, and published prices of the publications indexed are printed each half-year in the volume index.

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The Ice Problem in Engineering Work in Canada. By H. T. Barnes. *Engineering, 9th August*, 1907.

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Test of "Mouchel-Hennebique" Ferro-concrete Floors. Last month load tests were conducted on the three upper floors of the Girls' Friendly Lodge, Belfast, which has been built from the designs of Mr. H. A. Cutler, M.Inst.C.E., the city engineer. The panels tested on the first, second and third floors measured 23 ft. between the walls by 5 ft. 3 in. over one of the main beams which, together with the floor slabs, are built in accordance with the "Mouchel-Hennebique" system of ferro-concrete, the beams measuring 5 in. wide by 8 in. deep below the under side of the floor slabs, the latter being 3½ in. thick.

Each floor was loaded with bags of cement to the weight of six tons, equal to the superload of 112 lb. per sq. ft. of floor surface, or double the normal load demanded by the specification.

The maximum deflection measured was ⅛ in. at the middle of the first floor beam, and a few hours after removal of the load the beam regained its original form, thus demonstrating the perfect elasticity of the construction within the limits of stress involved.

As the maximum deflection under double the normal load was less than $\frac{1}{1000}$ of the span, the results of this test must be regarded as highly satisfactory.

TRADE LITERATURE.

Michael Pal & Co., Manchester. Booklet dealing with steam turbine fans. This type of fan is driven by a small steam turbine, which is fixed on the shaft of the fan. The latest pattern is considerably improved, as in the case of horizontal shafting the bearing is fitted with a double ring lubricator, and provided with two glands; thus dirt is excluded. A further improvement consists in the arrangement by which the glands can be tightened without disarranging the fan itself. The turbine wheel is provided with two holes, through which the glands can be reached, and the larger sizes have these holes also on the casing cover of the turbine, thus rendering the unscrewing of the cover for this purpose unnecessary.

The propeller fans in the smaller sizes can be used for ventilating rooms by the low pressure steam of heating plants, where a steam pressure of about 3 lb. per sq. in. will suffice to drive the fan.

"The Art of Cutting Metals." By Frederick W. Taylor, M.E., Sc.D., which was the Presidential address presented at the last annual meeting of the American Society of Mechanical Engineers, has been reprinted and bound in cloth by the society, price $3.00. This or any other publication of the society may be had by addressing the secretary, 29, West 39th Street, New York. It is not necessary to send orders through members.

American Locomotive Co., 26, Victoria Street, S.W. Pamphlet dealing with six-wheel type switching locomotives, being the ninth of their series of booklets covering the standard types of locomotives manufactured by this firm. Also booklets dealing with eight-wheel type passenger locomotives and rotary snow ploughs.

Hans Renold, Ltd., Manchester. New edition of their catalogue dealing with the firm's well-known silent chain, and especially with the improvements introduced in the patent bearing type.

Dartium Syndicate, Ltd., 28, Basinghall Street, E.C. Booklet entitled "How to make Steel Castings and Tool Steel in the ordinary Iron or Brass Foundry by means of the 'Dartium' process."

S. Wolf & Co., 138, Southwark Street, S.E. Catalogue of portable electric tools, comprising drilling and grinding machines working with single, two, three-phase and continuous current up to 500 volts.

Pearson, Sons & Co., Ltd., Nitshill, Glasgow. Booklet entitled "The Economical Use of Coal in Steam Boiler Furnaces," and dealing with an apparatus for improving combustion.

British Gas Furnace and Tool Co., Ltd., Corporation Street, Birmingham. New list of hardening shop appliances, dealing more particularly with furnaces for tool hardening, &c.

Haste Pump Co., Ltd., Openshaw, Manchester. Catalogue of rotary pumps, air pumps of various types and surface condensers.

Ruston, Proctor & Co., Ltd., Lincoln. Booklet containing particulars of this firm's exhibits at the Royal Show held at Lincoln.

B. J. Hall & Co., Ltd., 39, Victoria Street, S.W. List section No. 4 of drawing office furniture.

The Consett Iron Co., Ltd. Pocket catalogue of pig iron, steel plates, shearings and sections.

Crompton & Co., Ltd., Salisbury House, London Wall, E.C. List D 29 of ceiling fans.

MANUFACTURERS' NOTES.

The Klein Engineering Co., Ltd., Manchester, inform us that they have received orders recently for the following plants. Per Siemens Bros., Dynamo Works, Ltd., Barometric Jet Condensing Plant for 32,000 lbs. of steam per hour, to be erected at the Ark Mill, Bredbury. Barometric Jet Condensing Plant and Cooler to deal with 17,000 lbs. of steam per hour, for the Falcon Mill, Bolton. One Klein Barometric Jet Condensing Plant for the Huddersfield Corporation, to deal with 30,000 lbs. of steam per hour.

The above three plants are intended to give a vacuum of 28 in. and to work in conjunction with Exhaust Steam Turbines.

Per Williams & Robinson, Ltd. One Barometric Jet Condensing Plant, to deal with 35,250 lbs. of steam per hour, and to give a vacuum of $27\frac{1}{2}$ in. This plant is also to work in conjunction with an Exhaust Steam Turbine.

Barometric Jet Condensing Plants and Coolers have also been put in operation quite recently for Messrs. John Brown & Co., Atlas Works, Sheffield, and at the Bolton Corporation Electricity Works. They have also in hand a Barometric Counter-Current Jet Condensing Plant for Bombay.

Gilbert Little Co., Ltd., Bradford. The contract for the structural steel buildings for the gas-producer and boiler-houses, along with the coal conveyors, elevators, overhead storage bunkers and accessories, for the new branch of the Clarence Steel Works, now being erected on the Manchester Ship Canal, has been placed with the above-mentioned firm.

Messrs. Bradbury & Co., Ltd., Sewing Machine and Tool Makers, Oldham. The accounts of this firm for the past half-year show a nett profit of £1,414 after allowing full depreciation and paying the interest on the Debenture Capital. It is some years since the company made a profit and we hope this is a sign of better results in the future.

Our German Agency. We are pleased to announce that we have appointed as sole agent for advertisements in Germany, Mr. Friedrich Lichfeldt, of Berlin, S.W., 68, Lindenstrasse 2, with whom intending Continental clients should communicate.

PRIZE COMPETITIONS FOR ENGINEERS.

In connection with the Second Prize Competition, we regret to have to announce that owing to the elementary and unsatisfactory character of the articles submitted, we have not felt justified in making any award.

Competitors without exception took the first subject, viz.: Live Steam Feed Heating, and confined their efforts to a mere description of existing types of live steam feed heaters. Not one considered the efficiency of the method, or examined the question as to whether it was thermodynamically good or bad. A knowledge of the physical causes which produce an economy when this method of feed heating is adopted is of great importance and interest, and in the hope that competitors will be stimulated to go more carefully into the subject we again offer the prize of £10, under the conditions stated opposite, for the best article. Papers must be sent in on or before December 1st.

THIRD PRIZE COMPETITION.

The Third Prize Competition relates to Workshop Practice, and is limited to Works Managers, Foremen, and those under their charge, to provide an opportunity of bringing their practical ideas and experiences into print.

Three prizes are offered—one of £5, one of £2, and one of £1—for the best short article describing and illustrating any emergency device or any job which has taxed the ingenuity of the machinist, pattern maker, fitter or foundry operator.

Instructions and Conditions.

Articles must be written on one side of the paper only, and be signed by the competitor.

Drawings and sketches must be on separate sheets of paper.

A short biographical sketch of the competitor's technical experience should accompany the article.

The right is reserved of publishing the prize article, and also any of the others sent in; but in the case of the latter, payment will be made for the same at our usual scale rates.

The Editor's decision in all matters connected with the competitions shall be final, and binding on all the competitors.

All articles should be addressed to the Editor of The Engineering Review, 104, High Holborn, London, W.C., and marked on the outside, "Competition," and the same must be received not later than November 1st.